

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION
SPONSORED PROJECT INITIATION

Date: 10/30/78

Project Title: EW Software Engineering

Project No: A-2259

Project Director: Mr. M. A. Lipscomb

Sponsor: Warner Robins ALC/PPZBB; Robins AFB, GA 31098

Agreement Period: From 10/4/78 Until 10/31/79 (Del. Order Term)

Type Agreement: Delivery Order No. 0004 under F09603-78-G-4368

Amount: \$45,000

Reports Required: Monthly Status Letters; Test Plans; Development Spec's.; Product Spec's.;
Software Delivery Doc.; Final Engineering Report.

Sponsor Contact Person (s):

Technical Matters

John Louth/MMRREC/2896
Harry B. Jennings/MMRRA/3140
Electronics Engineer
Simulation & Analysis Section
WR-ALC
Robins AFB, Ga. 31098
Phone: 912-926-2896 & 3140

Contractual Matters

(thru OCA)
Office of Naval Research
Resident Representative
325 Hinman Research Bldg.
Georgia Institute of Technology
Atlanta, GA 30332

Defense Priority Rating: DO-A7 under DMS Reg. 1.

Assigned to: Systems Engineering Division (School/Laboratory)

COPIES TO:

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SPONSORED PROJECT TERMINATION SHEETDate 8/11/83

Project Title: EW Software Engineering

Project No: A-2259

Project Director: M. A. Lipscomb

Sponsor: Warner Robins ALC/PPZBB; Robins AFB, GA 31098

Effective Termination Date: 10/31/79Clearance of Accounting Charges: 10/31/79

Grant/Contract Closeout Actions Remaining:

- ☒ Final Invoice ~~and Closing Documents~~
- ☐ Final Fiscal Report
- ☒ Final Report of Inventions - Patent Questionnaire being sent to SEL
- ☒ Govt. Property Inventory & Related Certificate
- ☐ Classified Material Certificate
- ☐ Other _____

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ENGINEERING EXPERIMENT STATION

GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

27 November 1978

Warner Robins Air Logistics Center
Robins Air Force Base
Georgia 31098

Attention: Mr. Robert E. Webb

Reference: F09603-78-G-4368-0004

Subject: Monthly Status Report No. 1

Gentlemen:

A summary of the progress on the reference contract for the period 1 October to 31 October is contained herein.

The purpose of this effort is to restructure the AN/ALR-46 software module Emitter Trackfile Entry using structured programming techniques to enhance the maintainability of the software, and to determine the extent to which this restructuring degrades the performance of the module.

Summary of Technical Efforts

Technical efforts thus far have been limited to the review of documentation at the Orientation Design Review. See "Visits" below.

Visits

On 24 and 25 October 1978, representatives of Georgia Tech attended the Orientation Design Review, held at WR-ALC in accordance with paragraph 3.4.1 of the contract. Attending were, representing WR-ALC: John Louth, Harry Jennings, and Bill Calkins; and representing Georgia Tech: Andy Lipscomb, Rick Thomas and Tom Miller. Mr. Calkins was designated project monitor for WR-ALC.

The principal topic of the meeting was the availability of documentation of the ETE module as well as documentation and listings of the AN/ALR-46 software as a whole. The principal items discussed were:

Three listings of the AN/ALR-46 software: A listing of the operational flight program (version V8) classified SECRET, a listing of a second version classified CONFIDENTIAL (the Swiss version), and a machine

readable listing of the Swiss version deliverable on magnetic tape.

A report prepared by Dalmo Victor documenting the AN/ALR-46 software.

24 hours of videotape containing a description of the AN/ALR-46 software.

All listings are available for transport to Georgia Tech. Mr. Calkins agreed to obtain these listings and forward them to Georgia Tech. We are to inform him of the required format for the magnetic tape.

The Dalmo Victor report is not available for transport to Georgia Tech pending formal acceptance of the report by WR-ALC.

The videotape may be copied and the copies transported to Tech. It was agreed that Georgia Tech will send someone to copy the tapes when they are required.

The next required meeting between Georgia Tech and WR-ALC personnel, the Technical Coordination meeting, was tentatively scheduled for December 12, 1978. See the section "Schedule", however.

Efforts Expended

The following is the total effort expended, in man-hours, through 30 October 1978.

<u>Personnel</u>	<u>Man-hours</u>
Lipscomb, M. A. Project Director	40
Thomas, R. E. Assistant Research Engineer	16

For the period 1 October through 30 October 1978 a total of \$931.60 was spent. The project ceiling price is \$45,000 leaving a balance of \$44,068.40

Schedule

It became apparent at the Orientation Design Review that Georgia Tech's efforts, if begun immediately, could be hampered by a lack of documentation on the system. Additional documentation, particularly the Dalmo Victor report, the principal document relating to ETE, may be available at a later date; thus our effectiveness will be enhanced by postponing the start of technical efforts. Such a postponement was discussed with Mr. Jennings and Mr. Calkins on 13 November 1978 by telephone. Both agreed tentatively to the postponement. Mr. Jennings agreed to obtain the necessary contract extension and requested a revised schedule for the task. The proposed revised schedule, showing the start of technical efforts on 15 January 1979, is attached.

A formal request for a contract extension is being prepared.

It is agreed that available documentation will be forwarded to Georgia Tech as early as possible. Mr. Jennings noted, however, that the AN/ALR-46 software is currently being revised, and that listings should be withheld until the revised version is available.

Respectfully submitted,

M. A. Lipscomb
Project Director

APPROVED:

T. M. Miller, Head
Defense Systems Branch
Systems Engineering Division

MAL/ss
Enc.

Suggested Revised Schedule

Day 1 at January 15, 1979

Day 270 at October 12, 1979

<u>Day</u>	<u>Event</u>	<u>Activity</u>
1	Start of Technical Efforts	Software Design (through Day 135)
15		
30	Technical Coordination Meeting	
45		
60		
75	Preliminary Design Review	
90		
105		
120		
135	Critical Design Review	Software Implementation (through Day 210)
150		
165		
180		
195		
210		Software Testing (through Day 255)
225	Intermediate Design Review	Testing at EES (210-225)
240		Rehost and test at WR-ALC (225-255)
255		
270	Final Design Review	



ENGINEERING EXPERIMENT STATION

GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

13 December 1978

Warner Robins Air Logistics Center
Robins Air Force Base
Georgia 31098

Attention: Mr. Robert E. Webb

Reference: F09603-78-G-4368-0004

Subject: Monthly Status Report No. 2

Gentlemen:

A summary of the progress on the reference contract for the period 1 November 1978 to 30 November 1978 is contained herein.

The purpose of this effort is to restructure the AN/ALR-46 software module Emitter Trackfile Entry using structured programming techniques to enhance the maintainability of the software, and to determine the extent to which this restructuring degrades the performance of the module.

Summary of Technical Efforts

Technical efforts thus far have been limited to the review of documentation at the Orientation Design Review. It became apparent at the Orientation Design Review that Georgia Tech's efforts, if begun immediately, could be hampered by a lack of documentation on the system. Additional documentation may be available at a later date; thus our effectiveness will be enhanced by postponing the start of technical efforts. Such a postponement was discussed with Mr. Jennings and Mr. Calkins on 13 November 1978 by telephone. Both agreed tentatively to the postponement. Mr. Jennings agreed to obtain the necessary contract extension and requested a revised schedule for the task.

Efforts Expended

The following is the total effort expended, in man-hours, during the month of November.

<u>Personnel</u>	<u>Man-hours</u>	
	<u>Month</u>	<u>Cumulative</u>
Lipscomb, M. A. Project Director	8	48
Thomas, R. E. Asst. Res. Engineer	0	16

For the period October 1978 a total of \$931.60 was spent. This is also the

cumulative total as of 31 October 1978. The project ceiling price is \$45,000 leaving a balance of \$44,068.40 as of 31 October 1978.

Schedule

The start of technical efforts has been postponed until January 15, 1979. A tentative revised schedule was submitted with Monthly Status Report No. 1 (27 November 1978). The project monitors, Mr. Harry Jennings and Mr. Bill Calkins have agreed to the postponement. A formal request for a contract extension is being prepared.

Respectfully submitted,

M. A. Lipscomb
Project Director

APPROVED:

T. M. Miller, Head
Defense Systems Branch
Systems Engineering Division

ss
Enc.



ENGINEERING EXPERIMENT STATION

GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

18 January 1979

Warner Robins Air Logistics Center
Robins Air Force Base
Georgia 31098

Attention: Mr. Robert E. Webb

Reference: F09603-78-G-4368 Order No. 0004

Subject: Monthly Status Report No. 3

Gentlemen:

A summary of the progress on the reference contract for the period 1 December 1978 to 31 December 1978 is contained herein.

The purpose of this effort is to restructure the AN/ALR-46 software module Emitter Trackfile Entry using structured programming techniques to enhance the maintainability of the software, and to determine the extent to which this restructuring degrades the performance of the module.

Summary of Technical Efforts

Technical efforts thus far have been limited to the review of documentation at the Orientation Design Review. It became apparent at the Orientation Design Review that Georgia Tech's efforts, if begun immediately, could be hampered by a lack of documentation on the system. Additional documentation may be available at a later date; thus our effectiveness will be enhanced by postponing the start of technical efforts. Such a postponement was discussed with Mr. Jennings and Mr. Calkins on 13 November 1978 by telephone. Both agreed tentatively to the postponement. Mr. Jennings agreed to obtain the necessary contract extension and requested a revised schedule for the task.

Efforts Expended

The following is the total effort expended, in man-hours, during the month of December.

<u>Personnel</u>	<u>Man-hours</u>	
	<u>Month</u>	<u>Cumulative</u>
Lipscomb, M. A. Project Director	3	55
Thomas, R. E. Asst. Res. Engineer	0	16

For the period November 1978 a total of \$229.49 was spent. Bringing the cumulative total as of 30 November 1978 to \$1,161.09. The project ceiling price is \$45,000 leaving a balance of \$43,838.91 as of 30 November 1978.

Schedule

The start of technical efforts was postponed until January 15, 1979. A tentative revised schedule was submitted with Monthly Status Report No. 1 (27 November 1978). The project monitors, Mr. Harry Jennings and Mr. Bill Calkins have agreed to the postponement. A formal request for a contract extension is being prepared.


Future Efforts

Technical efforts will begin January 15, as scheduled. In January we will begin analysis of the available documentation. The objectives of the initial analysis are:

- to isolate those structural and functional characteristics of the existing program which will require additional clarification by WR-ALC personnel
- to derive a functional specification for the restructured program
- to formulate a procedure for the restructuring the program

In addition we will conduct a brief review of the technical literature in a search for precedents and existing methods for program transformation.

Respectfully submitted,


M. A. Lipscomb
Project Director

APPROVED:

T. M. Miller, Head
Defense Systems Branch
Systems Engineering Division

ss
Enc.



ENGINEERING EXPERIMENT STATION

GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

22 February 1979

Warner Robins Air Logistics Center
Robins Air Force Base
Georgia 31098

Attention: Mr. Robert E. Webb

Reference: F09603-78-G-4368 Order No. 0004

Subject: Monthly Status Report No. 4

Gentlemen:

A summary of the progress on the reference contract for the period 1 January 1979 to 31 January 1979 is contained herein.

The purpose of this effort is to restructure the AN/ALR-46 software module Emitter Trackfile Entry using structured programming techniques to enhance the maintainability of the software, and to determine the extent to which this restructuring degrades the performance of the module.

Summary of Technical Efforts

Technical efforts began January 15, 1979. Initial efforts were directed toward familiarizing the project staff with the ETE documentation and establishing a correspondence between the documentation and program listings.

Efforts Expended

The following is the total technical effort expended, in man-hours, during the month of January.

<u>Personnel</u>	<u>Man-hours</u>	
	<u>Month</u>	<u>Cumulative</u>
Lipscomb, M. A. Project Director	44	99
Thomas, R. E. Asst. Res. Engineer	0	16
Hoyer, K. M. Co-op	24	24

For the period December 1978 a total of \$118.91 was spent. Bringing the cumulative total as of 31 December 1978 to \$1,280.00. The project ceiling price is \$45,000 leaving a balance of \$43,720.00 as of 31 December 1978.

Schedule

The preliminary functional specification for the restructured program should be completed in March. Thus a technical coordination meeting early in April is indicated.

Future Efforts

In February we will continue analysis of the available documentation. The objectives of the initial analysis are:

- to isolate those structural and functional characteristics of the existing program which will require additional clarification by WR-ALC personnel
- to derive a functional specification for the restructured program
- to formulate a procedure for restructuring the program

Respectfully submitted,

✓
M. A. Lipscomb
Project Director

APPROVED:

✓
T. M. Miller, Head
Defense Systems Branch
Systems Engineering Division

ss
Enc.



ENGINEERING EXPERIMENT STATION

GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

9 March 1979

Warner Robins Air Logistics Center
Robins Air Force Base
Georgia 31098

Attention: Mr. Robert E. Webb

Reference: F09603-78-G-4368 Order No. 0004

Subject: Monthly Status Report No. 5

Gentlemen:

A summary of the progress on the reference contract for the period 1 February 1979 to 28 February 1979 is contained herein.

The purpose of this effort is to restructure the AN/ALR-46 software module Emitter Trackfile Entry using structured programming techniques to enhance the maintainability of the software, and to determine the extent to which this restructuring degrades the performance of the module.

Summary of Technical Efforts

Technical efforts in February were directed toward achieving the first goal of the project, a functional specification for the restructured ETE, and evaluating means of extending the team's access to appropriate computing facilities.

The first goal of the project is to define the operation of the existing program so that the definition will serve as a functional specification for the restructured version. This definition will include a complete description of the logic flow, and an algorithmic description of the data processing (matching, sorting, etc.) routines.

The first task has been to delimit the extent of ETE within the Operational Flight Program and to isolate the principle subroutines identified on the flowchart. This has been done.

The second task is to identify communication links between routines, and conditions under which the routines are executed. A procedure for doing so has been established and the task started. The procedure involves the collection and indexing of data by routine and by major variables.

The team's access to an appropriate computer, that is, a facility which is cleared for CONFIDENTIAL material and is capable of accepting NOVA assembler code, is currently limited. This limitation is not, at this time, a constraint, since very little computing is required in the initial phases of the project. Later phases of the project can be accomplished more efficiently, however, if the limitation is removed. Thus, Mr. Vogt is evaluating various options for extending the current capability.

Efforts Expended

The following is the total technical effort expended, in man-hours, during the month of February.

<u>Personnel</u>	<u>Man-hours</u>	
	<u>Month</u>	<u>Cumulative</u>
Lipscomb, M. A. Project Director	108	207
Miller, T. M. Sr. Res. Engineer	22	22
Thomas, R. E. Asst. Res. Engineer	0	16
Vogt, J. V. Asst. Res. Engineer	22	22
Hoyer, K. M. Co-op	132	156

For the period January 1979 a total of \$924.47 was spent. Bringing the cumulative total as of 31 January 1979 to \$2,204.47. The project ceiling price is \$45,000 leaving a balance of \$42,795.53 as of 31 January 1979.

Schedule

The preliminary functional specification for the restructured program should be completed in April. Thus a technical coordination meeting early in May is indicated.

Future Efforts

When the data collection task described under Technical efforts has been completed, the project team will be able to assemble a description of the logic flow, identify the principle data processing routines, and describe the data elements processed by these routines. At that point the team will have sufficient information in hand to conduct focused interviews with WR-ALC personnel to obtain precise algorithmic descriptions of the routines.

APPROVED:

Respectfully submitted,

T. M. Miller, Head
Defense Systems Branch
Systems Engineering Division
ss
Enc.

M. A. Lipscomb
Project Director



ENGINEERING EXPERIMENT STATION

GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

9 April 1979

Warner Robins Air Logistics Center
Robins Air Force Base
Georgia 31098

Attention: Mr. Robert E. Webb

Reference: F09603-78-G-4368 Order No. 0004

Subject: Monthly Status Report No. 6

Gentlemen:

A summary of the progress on the reference contract for the period 1 March 1979 to 31 March 1979 is contained herein.

The purpose of this effort is to restructure the AN/ALR-46 software module Emitter Trackfile Entry (ETE) using structured programming techniques to enhance the maintainability of the software, and to determine the extent to which this restructuring degrades the performance of the module.

Summary of Technical Efforts

Technical efforts in March were directed toward achieving the first goal of the project, a functional specification for the restructured ETE. The project team continued to analyze the existing code, collecting data describing communications between modules within the program. As of 1 April, this task was approximately 25% complete.

Efforts Expended

The following is the total technical effort expended, in man-hours, during the month of March.

<u>Personnel</u>	<u>Man-hours</u>	
	<u>Month</u>	<u>Cumulative</u>
Lipscomb, M. A. Project Director	65	272
Miller, T. M. Sr. Res. Engineer	9	31
Thomas, R. E. Asst. Res. Engineer	0	16
Vogt, J. V. Asst. Res. Engineer	11	33
Hoyer, K. M. Co-op	81	237

For the period March 1979 a total of \$3,440.84 was spent, making the cumulative total as of 31 March 1979 to \$5,645.31. The project ceiling price is \$45,000 leaving a balance of \$39,354.69 as of 31 March 1979.

Schedule

The proposed schedule of tasks for restructuring the ETE program assumed that sufficient documentation would be provided to Georgia Tech such that only a cursory analysis of the software would be necessary to formulate a preliminary computer program functional specification adequate for initial design purposes. However, the level of detail provided in the documentation of the ETE program has necessitated that an in depth analysis of the software be performed to generate the required functional specification for the entire ETE program. This additional effort coupled with project staffing has resulted in the original program schedule not being maintained. However, the detailed initial analyses of the software should reduce the time required to perform the remaining tasks.

Recently, Mr. Harry Jennings at WR-ALC requested that Georgia Tech review the schedule of tasks to determine if a sample of restructured computer code could be produced quickly without increasing the total cost of the project. Such an effort would require that specification, design, and coding be initially performed on a subset of ETE as opposed to completing the formulation of a functional specification on the entire ETE program. In addition, this effort would provide preliminary coding output for discussion at the project performance review tentatively scheduled for May 1979. A revised schedule containing a no cost time extension will be prepared and submitted to WR-ALC for approval during the month of April.

Future Efforts

In April, the bulk of the team's effort will be directed toward completing the initial analysis of the software. In addition, the alternative of completely restructuring a subset of ETE for early delivery will be evaluated, and a set of programming standards describing the restructuring method will be formulated.

APPROVED:

Respectfully submitted,

T. M. Miller, Head
Defense Systems Branch
Systems Engineering Division
ss
Enc.

M. A. Lipscomb
Project Director



ENGINEERING EXPERIMENT STATION

GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

23 May 1979

Warner Robins Air Logistics Center
Robins Air Force Base
Georgia 31098

Attention: Mr. Robert E. Webb

Reference: F09603-78-G-4368 Order No. 0004

Subject: Monthly Status Report No. 7

Gentlemen:

A summary of the progress on the reference contract for the period 1 April 1979 to 30 April 1979 is contained herein.

The purpose of this effort is to restructure the AN/ALR-46 software module Emitter Trackfile Entry (ETE) using structured programming techniques to enhance the maintainability of the software, and to determine the extent to which this restructuring degrades the performance of the module.

Summary of Technical Efforts

Technical efforts in April were directed toward early completion of the restructuring effort through the coding stage for a subset of the ETE module. This subset will be delivered in May, along with a presentation describing the team's experience and preliminary findings, to the project monitors and other interested parties for review and evaluation. Early delivery of a subset of the code will allow incorporation of the sponsor's comments and criticisms into the coding standards prior to the completion of the task.

Efforts Expended

The following is the total technical effort expended, in man-hours, during the month of April.

<u>Personnel</u>	<u>Man-hours</u>	
	<u>Month</u>	<u>Cumulative</u>
Lipscomb, M. A. Project Director	181	453
Miller, T. M. Sr. Res. Engineer	0	31
Thomas, R. E. Asst. Res. Engineer	0	16
Vogt, J. V. Asst. Res. Engineer	0	33
Hoyer, K. M. Co-op	30	267
Worsham, J. Co-op	22	22
Zimmer, R. P. Division Chief	7	7

For the period March 1979 a total of \$3,440.84 was spent, making the cumulative total as of 31 March 1979 to \$5,645.31. The project ceiling price is \$45,000 leaving a balance of \$39,354.69 as of 31 March 1979.

Schedule

The subset of ETE for which coding will be completed in May represents 37% of the original code. In addition, preliminary analysis has been completed for over 50% of the original code. Early completion of a portion of the code may require some adjustment of the project schedule. A revised schedule, if required, will be submitted following completion of this task.

Future Efforts

The team will continue to work toward delivery of a subset of restructured code in mid-May. Following this delivery the team will return to the task of developing a specification for restructuring the remainder of the code. In addition, the restructuring method will be reformulated to incorporate suggestions put forth by the project sponsors at the May meeting.

APPROVED:

Respectfully submitted,

T. M. Miller, Head
Defense Systems Branch
Systems Engineering Division
ss
Enc.

M. A. Lipscomb
Project Director



ENGINEERING EXPERIMENT STATION

GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

4 June 1979

Warner Robins Air Logistics Center
Robins Air Force Base
Georgia 31098

Attention: Mr. Robert E. Webb
Reference: F09603-78-G-4368 Order No. 0004
Subject: Monthly Status Report No. 8

Gentlemen:

A summary of the progress on the reference contract for the period 1 May 1979 to 31 May 1979 is contained herein.

The purpose of this effort is to restructure the AN/ALR-46 software module Emitter Trackfile Entry (ETE) using structured programming techniques to enhance the maintainability of the software, and to determine the extent to which this restructuring degrades the performance of the module.

Summary of Technical Efforts

Technical efforts in May were directed primarily toward early completion of the restructuring effort through the coding stage for a subset of the ETE module. This subset was delivered in May, along with a presentation describing the team's experience and preliminary findings, to the project monitors and other interested parties for review and evaluation. Early delivery of a subset of the code will allow incorporation of the sponsor's comments and criticisms into the coding standards prior to the completion of the task.

Efforts Expended

The following is the total technical effort expended, in man-hours, during the month of May.

<u>Personnel</u>	<u>Man-hours</u>	
	<u>Month</u>	<u>Cumulative</u>
Lipscomb, M. A. Project Director	151	606
Miller, T. M. Sr. Res. Engineer	0	31
McDougal, G. F. Research Engineer	22	22
Thomas, R. E. Asst. Res. Engineer	0	16
Vogt, J. V. Asst. Res. Engineer	0	33
Hoyer, K. M. Co-op	35	302
Worsham, J. Co-op	27	49
Zimmer, R. P. Division Chief	0	7

For the period April 1979 a total of \$2,468.32 was spent, making the cumulative total as of 30 April 1979 to \$10,252.99. The project ceiling price is \$45,000 leaving a balance of \$34,747.01 as of 30 April 1979.

Schedule

The subset of ETE for which coding will be completed in May represents 37% of the original code. In addition, preliminary analysis has been completed for over 50% of the original code. Early completion of a portion of the code may require some adjustment of the project schedule. A revised schedule, if required, will be submitted following completion of this task.

A request for a no cost extension of the project performance period, providing for termination of the project on 30 September 1979 has been initiated through the Georgia Tech Office of Contract Administration.

Future Efforts

The team will continue the task of developing a specification for restructuring the remainder of the code. In addition, the restructuring method will be reformulated to incorporate suggestions put forth by the project sponsors at the May meeting.

APPROVED:

Respectfully submitted, /

T. M. Miller, Head
Defense Systems Branch
Systems Engineering Division
ss
Enc.

M. A. Lipscomb
Project Director



ENGINEERING EXPERIMENT STATION

GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

5 July 1979

Warner Robins Air Logistics Center
Robins Air Force Base
Georgia 31098

Attention: Mr. Robert E. Webb

Reference: F09603-78-G-4368 Order No. 0004

Subject: Monthly Status Report No. 9

Gentlemen:

A summary of the progress on the reference contract for the period 1 June 1979 to 30 June 1979 is contained herein.

The purpose of this effort is to restructure the AN/ALR-46 software module Emitter Trackfile Entry (ETE) using structured programming techniques to enhance the maintainability of the software, and to determine the extent to which this restructuring degrades the performance of the module.

Summary of Technical Efforts

Technical efforts in June were directed toward completion of the initial analysis of the software, and the formulation of restructuring standards. The initial analysis has now been completed for all of the original code and work has begun on a draft functional specification. Restructuring standards are approximately 30% complete.

Efforts Expended

The following is the total technical effort expended, in man-hours, during the month of June.

<u>Personnel</u>	<u>Man-hours</u>	
	<u>Month</u>	<u>Cumulative</u>
Lipscomb, M. A. Project Director	102	708
Miller, T. M. Sr. Res. Engineer	30	61
Gibbons, J. Sr. Res. Engineer	11	11
McDougal, G. F. Research Engineer II	0	22
Thomas, R. E. Res. Engineer II	0	16
Vogt, J. V. Res. Engineer II	0	33
Cockerham, B. Grad. Res. Assistant	80	80
Russell, C. Co-op	2	2
Hoyer, K. M. Co-op	11	313
Worsham, J. Co-op	85	134
Zimmer, R. P. Principal Research Engineer	0	7

For the period May 1979 a total of \$3,269.61 was spent, making the cumulative total as of 31 May 1979 to \$13,522.60. The project ceiling price is \$45,000 leaving a balance of \$31,477.40 as of 31 May 1979.

Schedule

Drafts of the functional specification and restructuring standards will be completed in July. A meeting is indicated near the end of July for review of these items by the sponsor's technical representatives.

Future Efforts

In July the team will concentrate primarily on completion of the functional specification and restructuring standards. Work will also begin on the test plan.

Monthly Status Report No. 9

5 July 1979

Contract No. F09603-78-G-4368-0004

Page 3

APPROVED:

Respectfully submitted,

T. M. Miller, Head
Defense Systems Division
Systems Engineering Laboratory

M. A. Lipscomb
Project Director

ss
Enc.



ENGINEERING EXPERIMENT STATION

GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

10 August 1979

Warner Robins Air Logistics Center
Robins Air Force Base
Georgia 31098

Attention: Mr. Robert E. Webb

Reference: F09603-78-G-4368 Order No. 0004

Subject: Monthly Status Report No. 10

Gentlemen:

A summary of the progress on the reference contract for the period 1 July 1979 to 31 July 1979 is contained herein.

The purpose of this effort is to restructure the AN/ALR-46 software module Emitter Trackfile Entry (ETE) using structured programming techniques to enhance the maintainability of the software, and to determine the extent to which this restructuring degrades the performance of the module.

Summary of Technical Efforts

Technical efforts in July were allocated to the following tasks:

1. Formulation of a draft functional specification for the software,
2. Formulation of the restructuring standards,
3. Formulation of a test plan for the restructured code,
4. Formulation of a specification for the test driver in which the restructured code will be tested.

The first draft of the functional specification is essentially complete. The restructuring standards and test plan specification are approximately 50% complete. The test driver specification will be completed early in August.

Efforts Expended

The following is the total technical effort expended, in man-hours, during the month of July.

<u>Personnel</u>	<u>Man-hours</u>	
	<u>Month</u>	<u>Cumulative</u>
Lipscomb, M. A. Project Director	196	904
Miller, T. M. Sr. Res. Engineer	11	72
Rusk, T. P. Sr. Res. Engineer	22	22
Gibbons, J. Sr. Res. Engineer	125	136
McDougal, G. F. Research Engineer II	0	22
Thomas, R. E. Res. Engineer II	0	16
Vogt, J. V. Res. Engineer II	0	33
Timar, J. J. Research Engineer II	15	15
Creswell, R. E. Research Engineer II	65	65
Thompson, W. K. Research Engineer I	108	108
Cockerham, B. Grad. Res. Assistant	152	232
Russell, C. Co-op	0	2
Hoyer, K. M. Co-op	0	313
Worsham, J. Co-op	0	134
Zimmer, R. P. Principal Research Engineer	0	7

For the period June 1979 a total of \$3,897.61 was spent, bringing the cumulative total as of 31 May 1979 to \$17,419.84. The project ceiling price is \$45,000 leaving a balance of \$27,580.16 as of 31 June 1979.

Schedule

In August, the first draft of the functional specification of the software will be completed. When the functional specification is completed, a meeting with the sponsor's technical representatives will be required for the purpose of reviewing the specification. The draft test plan, and draft restructuring standards will be presented at the same meeting.

Future Efforts

In August, work will continue on all of the above mentioned tasks. Following presentation of the various draft documents, efforts will be devoted to preparing a final functional specification, and the construction and validation of the test driver.

Respectfully submitted,

M. A. Lipscomb
Project Director

APPROVED:

T. M. Miller, Jr., Chief
Defense Systems Division
Systems Engineering Laboratory

ss
Enc.



ENGINEERING EXPERIMENT STATION

GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

6 September 1979

Warner Robins Air Logistics Center
Robins Air Force Base
Georgia 31098

Attention: Mr. Robert E. Webb
Reference: F09603-78-G-4368 Order No. 0004
Subject: Monthly Status Report No. 11

Gentlemen:

A summary of the progress on the reference contract for the period 1 August 1979 to 31 August 1979 is contained herein.

The purpose of this effort is to restructure the AN/ALR-46 software module Emitter Trackfile Entry (ETE) using structured programming techniques to enhance the maintainability of the software, and to determine the extent to which this restructuring degrades the performance of the module.

Summary of Technical Efforts

Technical efforts in August were allocated to the following tasks:

1. Formulation of a draft functional specification for the software,
2. Formulation of the restructuring standards,
3. Formulation of a test plan for the restructured code,
4. Formulation of a specification for the test driver in which the restructured code will be tested.

Drafts of all the above items were completed and presented to the sponsor's technical representatives at the Preliminary Design Review held at WR-ALC on 30 August 1979. The minutes of that meeting are attached.

Efforts Expended

The following is the total technical effort expended, in man-hours, during the month of August.

<u>Personnel</u>	<u>Man-hours</u>	
	<u>Month</u>	<u>Cumulative</u>
Lipscomb, M. A. Project Director	166	1070
Miller, T. M. Sr. Res. Engineer	10	82
Rusk, T. P. Sr. Res. Engineer	22	22
Gibbons, J. Sr. Res. Engineer	83	219
McDougal, G. F. Research Engineer II	0	22
Thomas, R. E. Res. Engineer II	0	16
Vogt, J. V. Res. Engineer II	0	33
Timar, J. J. Research Engineer II	0	15
Creswell, R. E. Research Engineer II	40	105
Thompson, W. K. Research Engineer I	32	140
Cockerham, B. Grad. Res. Assistant	160	392
Russell, C. Co-op	0	2
Hoyer, K. M. Co-op	0	313
Worsham, J. Co-op	0	134
Zimmer, R. P. Principal Research Engineer	0	7

For the period July 1979 a total of \$11,748.10 was spent, bringing the cumulative total as of 30 July 1979 to \$29,167.94. The project ceiling price is \$45,000 leaving a balance of \$15,832.16 as of 31 July 1979.

Schedule

The sponsor's representative and the Project Director agreed on a revised schedule for the project at the Preliminary Design Review. The revised schedule is included in the minutes. A formal request for a no-cost extension of the project will be initiated by Georgia Tech this month.

Future Efforts

In September, work will be initiated on the design specification for the software. Work will continue on the Test Plan. The Functional Specification will be completed.

Respectfully submitted,

M. A. Lipscomb
Project Director

APPROVED:

T. M. Miller, Jr., Chief
Defense Systems Division
Systems Engineering Laboratory

ss
Enc.



ENGINEERING EXPERIMENT STATION

GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

TECHNICAL MEMORANDUM

4 September 1979

TM-2259-10

TO: A-2259 File
FROM: M. A. Lipscomb
SUBJECT: Minutes of Preliminary Design Review

A Preliminary Design Review was held on August 30, 1979, at Warner Robins Air Logistics Center (WRALC) to discuss progress on Project A-2259, "Performance Analysis of Operational Flight Program Code Optimized for Maintainability." In attendance were Andy Lipscomb and John Gibbons from Georgia Tech and Harry Jennings, John Dickens, Bill Calkins, and John Little from WRALC. The meeting included a morning session, during which the attendees discussed progress to date on the project, and an afternoon session during which the attendees discussed future plans for the project.

In the morning session, Georgia Tech's representatives presented seven Technical Memoranda, four constituting a draft Functional Specification, two describing Restructuring Procedures employed in the initial phases of the task, and one containing a draft Test Plan for the restructured code. (A list of the Technical Memoranda is attached.) The documents will be reviewed by WRALC personnel and returned to Georgia Tech, with comments, at a future date (see the project schedule attached). The Functional Specification and Restructuring Procedures were not discussed in depth at this meeting. Andy Lipscomb noted, however, that although there had initially been some doubt as to the feasibility of extracting a sound Functional Specification from the existing code and available documentation without a large commitment of time from experienced WRALC engineers, the results obtained so far indicate that such a commitment will not be necessary; a review of the draft specification by WRALC engineers followed by a meeting to discuss questions raised by Georgia Tech and WRALC engineers will suffice. Further discussion of the schedule for this meeting was deferred until the afternoon session, as was a discussion of the draft Test Plan.

The remainder of the morning session was devoted to clarification of certain technical points relating to the operation of the existing programs. John Little answered questions posed by the Georgia Tech representatives.

During the afternoon session, attendees discussed the draft Test Plan, possibilities for the site of the final comparative testing of the original and restructured programs, a revised schedule for the project, and possibilities for further work following the termination of the current project.

John Gibbons described the Test Plan, which included preliminary specifications for both the test data, and the test driver, the program which will drive the original and restructured modules for the test, compare results for discrepancies, and measure differences in run time between the modules. Harry Jennings raised three points relating to the test procedures: first, WRALC engineers should review the test data prior to the test and, if required, suggest additions and modifications. Secondly, the test should be structured so as to provide explicit correspondence between the test results and requirements stated in the Functional Specification. Finally, the test data should be delivered to WRALC for future use in testing modifications to the program.

Andy Lipscomb asked about the availability of a suitable computer at WRALC for the comparative testing. Although Georgia Tech has facilities for assembling the restructured program and conducting the integration tests, no machine having the required security level for CONFIDENTIAL material has yet been identified for the comparative testing. Furthermore, several of Tech's engineers on the project will be in full-time residence at WRALC at the time of the tests. Bill Calkins, while emphasizing that he had no authority to commit government equipment to the project, state that an ECLIPSE S230 dedicated to use on the ALR-46 system is currently in procurement and will possibly be available for this task. Use of this machine could introduce a delay, since it may be out of commission, due to a move, at the time of the testing. Such a delay, if it occurs, will not be extensive, however, and will probably pose no problem. The attendees agreed to pursue the matter further at a future meeting when the availability of the machine, and the extent to which it will be needed in the testing can be determined with greater certainty.

A tentative schedule for the remainder of the project was agreed upon. This schedule is attached. The budget was also discussed. The project is currently within budget; there are, however, uncertainties regarding the effort required for the testing phase of the project. Estimates of this effort are being prepared and will be provided for review by the technical monitors.

Possibilities for further effort following the termination of the current project were discussed. The possibilities identified, some of which may involve Georgia Tech participation, included:

- * Redesign, at the functional level, of ETE (the current effort is limited to operational changes which will leave function unaffected).
- * Redesign of the entire ALR-46 Operational Flight Program
- * Redesign of the PRI deinterleave (PRIDE) routine (this effort is in progress at WRALC).
- * Rewrite of ETE in a higher order language, such as Pascal, for comparative testing.
- * Rewrite of ALR-46 software documentation.

Schedule

- September 14, 1979 - Revised Draft of Functional Specification returned to Tech following WRALC review
- September 21, 1979 - Meeting to review Functional Specification
- October 5, 1979 - Final Functional Specification mailed to WRALC
- October 19, 1979 - Functional Specification returned to Tech following WRALC review
- November 30, 1979 - Design Specification, Final Test Plan presented at WRALC
- January, 3, 1980 - Rehost and test restructured software. Software documentation delivered to WRALC
- January 32, 1980 - Final Engineering Report presented at WRALC. Project terminated.

Technical Memoranda Presented at the Preliminary Review

Relating to the Functional Specification:

TM-2259-4	Functional and Operational Description of ETE Part I - Match Routines
TM-2259-6	Functional and Operational Description of ETE Part II - Update Routines
TM-2259-7	Functional and Operational Description of ETE Part III - Data Structures
TM-2259-8	Functional and Operational Description of ETE Part IV - Preserved Modules

Relating to the Test Plan:

TM-2259-9	Preliminary Test Design for ALR-46 Structured Software
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Relating to the Restructuring Procedure:

TM-2259-3	Software Restructuring Procedure - Initial Analysis
TM-2259-5	Software Restructuring Procedure - Objectives Analysis

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Monthly Status Report No. 12



ENGINEERING EXPERIMENT STATION

GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

8 November 1979

Warner Robins Air Logistics Center
Robins Air Force Base
Georgia 31098

Attention: Mr. Robert E. Webb

Reference: F09603-78-G-4368 Order No. 0004

Subject: Monthly Status Report No. 13

Gentlemen:

A summary of the progress on the reference contract for the period 1 October 1979 to 31 October 1979 is contained herein.

The purpose of this effort is to restructure the AN/ALR-46 software module Emitter Trackfile Entry (ETE) using structured programming techniques to enhance the maintainability of the software, and to determine the extent to which this restructuring degrades the performance of the module.

Summary of Technical Efforts

Technical efforts in October were allocated to the following tasks:

1. Formulation of the functional specification
2. Formulation of the design specification
3. Construction of the test driver

The functional specification was completed. The design specification is approximately 25% complete. Efforts on the test driver thus far have been limited to the development of prototype programs which are being used to determine the technical requirements for the driver to achieve the desired timing resolution.

Efforts Expended

The following is the total technical effort expended, in man-hours, during the month of August.

<u>Personnel</u>	<u>Man-hours</u>	
	<u>Month</u>	<u>Cumulative</u>
Lipscomb, M. A. Project Director	123	1234
Miller, T. M. Sr. Res. Engineer	0	82
Rusk, T. P. Sr. Res. Engineer	0	22
Gibbons, J. Sr. Res. Engineer	0	219
McDougal, G. F. Research Engineer II	0	22
Thomas, R. E. Res. Engineer II	0	16
Vogt, J. V. Res. Engineer II	0	33
Timar, J. J. Research Engineer II	0	15
Creswell, R. E. Research Engineer II	0	105
Thompson, W. K. Research Engineer I	0	179
Cockerham, B. Grad. Res. Assistant	160	392
Russell, C. Co-op	0	2
Hoyer, K. M. Co-op	0	313
Worsham, J. Co-op	0	134
Zimmer, R. P. Principal Research Engineer	0	7
Ballentine, M.	39	0

Monthly Status Report No. 13

8 November 1979

Contract No. F09603-78-G-4368-0004

Page 3

For the period September 1979 a total of \$1,874.62 was spent, bringing the cumulative total as of 30 September 1979 to \$40,520.55. The project ceiling price is \$45,000 leaving a balance of \$4,479.15 as of 30 September 1979.

Schedule

The design specification will be completed in November. Coding and validation will be completed in December. The test driver will also be completed in December, assuming there are no unforeseen technical difficulties.

Future Efforts

The primary effort in November will be directed toward completion of the design specification. Coding and validation and developments of the test driver will be pursued in parallel.

Respectfully submitted,

M. A. Lipscomb
Project Director

APPROVED:

7
T. M. Miller, Jr., Chief
Defense Systems Division
Systems Engineering Laboratory

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ENGINEERING EXPERIMENT STATION

GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

10 December 1979

Warner Robins Air Logistics Center
Robins Air Force Base
Georgia 31098

Attention: Mr. Robert E. Webb

Reference: F09603-78-G-4368 Order No. 0004

Subject: Monthly Status Report No. 14

Gentlemen:

A summary of the progress on the reference contract for the period 1 November 1979 to 30 November 1979 is contained herein.

The purpose of this effort is to restructure the AN/ALR-46 software module Emitter Trackfile Entry (ETE) using structured programming techniques to enhance the maintainability of the software, and to determine the extent to which this restructuring degrades the performance of the module.

Summary of Technical Efforts

Technical efforts in October were allocated to the following tasks:

1. Formulation of the design specification
2. Coding of the restructured program
3. Construction of the test driver

The design specification is approximately 90% complete. Approximately 5% of the coding is complete. Efforts on the test driver thus far have been limited to the development of prototype programs which are being used to determine the technical requirements for the driver to achieve the desired timing resolution.

Efforts Expended

The following is the total technical effort expended, in man-hours, during the month of August.

<u>Personnel</u>	<u>Man-hours</u>	
	<u>Month</u>	<u>Cumulative</u>
Lipscomb, M. A. Project Director	93	1327
Miller, T. M. Sr. Res. Engineer	0	82
Rusk, T. P. Sr. Res. Engineer	0	22
Gibbons, J. Sr. Res. Engineer	0	219
McDougal, G. F. Research Engineer II	0	22
Thomas, R. E. Res. Engineer II	0	16
Vogt, J. V. Res. Engineer II	0	33
Timar, J. J. Research Engineer II	0	15
Creswell, R. E. Research Engineer II	0	105
Thompson, W. K. Research Engineer I	0	179
Cockerham, B. Grad. Res. Assistant	0	392
Russell, C. Co-op	0	2
Hoyer, K. M. Co-op	0	313
Worsham, J. Co-op	0	134
Zimmer, R. P. Principal Research Engineer	0	7
Ballentine, M. Graduate Res. Asst.	6	0

For the period October 1979 a total of \$4,254.54 was spent, bringing the cumulative total as of 31 October 1979 to \$44,775.09. The project ceiling price is \$45,000 leaving a balance of \$224.91 as of 31 October 1979.


Schedule

The design specification will be completed in December. Coding and validation will be completed in December. The test driver will be completed in January, assuming there are no unforeseen technical difficulties.


Future Efforts

The primary effort in December will be directed toward completion of coding and validation. Development of the test driver will be pursued in parallel.

Respectfully submitted,


M. A. Lipscomb
Project Director

APPROVED:


T. M. Miller, Jr., Chief
Defense Systems Division
Systems Engineering Laboratory

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ENGINEERING EXPERIMENT STATION

GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

8 January 1980

Warner Robins Air Logistics Center
Robins Air Force Base
Georgia 31098

Attention: Mr. Robert E. Webb

Reference: F09603-78-G-4368 Order No. 0004

Subject: Monthly Status Report No. 15

Gentlemen:

A summary of the progress on the reference contract for the period 1 December 1979 to 31 December 1979 is contained herein.

The purpose of this effort is to restructure the AN/ALR-46 software module Emitter Trackfile Entry (ETE) using structured programming techniques to enhance the maintainability of the software, and to determine the extent to which this restructuring degrades the performance of the module.

Summary of Technical Efforts

Technical efforts in December were allocated to the following tasks:

1. Formulation of the design specification
2. Construction of the test driver
3. Coding and validation.

The design specification is approximately 90% complete. A test driver suitable for use in code validation was completed. This driver is modifiable for future use in the comparative testing. Coding and validation is approximately 5% complete.

The completion, last month, of the Functional Specification led to changes in the project management plan. First, due to a lack of detailed documentation, the Functional Specification phase of the effort proved more time consuming and costly than had been expected. Secondly, a number of errors were discovered in the existing version of the software. The presence of these errors complicates the comparative testing phase of the effort. A detailed description of these problems was submitted to the sponsor with a request for additional funding in the amount of \$12,000.

Documentation

Technical memoranda are produced by project engineers for internal documentation of information and procedures relating to both technical and managerial aspects of the project. The following technical memoranda were produced in December

Technical Memoranda

Number

Subject

TM-A-2259-12

Minutes of the Critical Design Review

Meetings

A Critical Design Review was held Monday, December 17, 1979 at WR/ALC. Minutes of this meeting are attached.

Expenditures

For the period November 1979 a total of \$1,930.42 was spent, bringing the cumulative total as of 30 November 1979 to \$46,705.51. The project ceiling price is \$45,000 leaving a deficit of \$1,705.57 as of 30 November 1979.

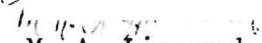
Schedule

Coding and validation will be completed in January. The test driver will be completed in January, and test data will be compiled for the comparative testing.

Future Work

The primary effort in January will be directed toward completion of coding and validation. Development of the comparative test data will be pursued in parallel.

Respectfully submitted,


M. A. Lipscomb
Project Director

APPROVED:

T. M. Miller, Jr., Chief
Defense Systems Division
Systems Engineering Laboratory

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ENGINEERING EXPERIMENT STATION

GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

TECHNICAL MEMORANDUM

8 January 1980

TM-A-2259-12

TO: File
FROM: M. A. Lipscomb
SUBJECT: Minutes of the Critical Design Review

The Critical Design Review was held December 17, 1979 at Warner Robins Air Logistics Center. In attendance were Harry Jennings, Bill Calkins, and John Little representing WR/ALC and Andy Lipscomb and Mike Ballentine representing Georgia Tech. The following topics were discussed:

1. The Functional (Part 1) Specification of ETE
2. Consideration in the use and availability of WR/ALC computing facilities.
3. The Design (Part 2) Specification of ETE

1. Functional Specification

Prior to the meeting, an advance copy of the final draft of the Functional Specification was provided for review by WR/ALC personnel. Mr. Little pointed out several errors in the draft and suggested some minor revisions, but expressed satisfaction with the overall content and format of the document. All the necessary revisions are restricted in scope.

2. Computing Facilities

A WR/ALC computer will be required for the comparative testing phase of the effort. Mr. Lipscomb stated that Tech engineers would require access to the WR/ALC Eclipse computer for two or three days, including exclusive use for several hours during the run-time comparisons, and that access during a second shift would be acceptable. Mr. Jennings stated that such a usage schedule should be acceptable to WR/ALC. Determination of an exact schedule for the testing was deferred until the next meeting.

Mr. Ballentine and Mr. Calkins discussed the technical aspects of the testing operation. No significant interfacing problems are foreseen. Mr. Calkins stated that any disk run on the WR/ALC Eclipse computer would have to be completely purged before it was removed from the secured facility; thus a backup copy of all software should be provided on magnetic tape. Mr. Calkins also suggested that the Tech engineers bring a copy of the RDOS operating system used in the program development on Georgia Tech's Eclipse computer.

3. Design Specification

Mr. Lipscomb presented a preliminary draft of the Design Specification. The remainder of the meeting was spent in a detailed walk-through of the software design.



ENGINEERING EXPERIMENT STATION

GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

4 February 1980

Warner Robins Air Logistics Center
Robins Air Force Base
Georgia 31098

Attention: Mr. Robert E. Webb

Reference: F09603-78-G-4368 Order No. 0004

Subject: Monthly Status Report No. 16

Gentlemen:

A summary of the progress on the reference contract for the period 1 January 1980 to 31 January 1980 is contained herein.

The purpose of this effort is to restructure the AN/ALR-46 software module Emitter Trackfile Entry (ETE) using structured programming techniques to enhance the maintainability of the software, and to determine the extent to which this restructuring degrades the performance of the module.

Summary of Technical Efforts

Technical efforts in January were allocated to the following tasks:

1. Formulation of the design specification
2. Coding and validation.

Technical work on the design specification is complete. Coding and validation is approximately 25% complete.

Effort Expended

A record of the technical effort expended in the month of January follows:

<u>Professional Personnel</u>	<u>Man-Hours</u>	
	<u>Monthly</u>	<u>Cumulative</u>
Cockerham, B. C. Research Scientist I	98	98

Expenditures

For the period December 1979 a total of \$920.99 was spent, bringing the cumulative total as of 30 December 1979 to \$47,626.50. The project ceiling price is \$45,000 leaving a deficit of \$2,626.50 as of 30 December 1979. The estimated expenditures for January is \$1,000, for an estimated deficit, as of 31 January 1980 of \$3,622.50. A request for additional funding in the amount of \$12,000 was submitted to WR-ALC on 17 January 1980.

Schedule

Progress on the project has been slower than expected in December and January due to the project cost overrun, and the diversion of project personnel to other projects which have been designated by WR-ALC as being of higher priority. A revised schedule for the project will be prepared in February and submitted with the next Monthly Status Report.

Future Work

The primary effort in February will be directed toward completion of coding and validation. Development of the comparative test data will be pursued in parallel.

Respectfully submitted,

M. A. Lipscomb
Project Director

APPROVED:

/T. M. Miller, Jr., Chief
Defense Systems Division
Systems Engineering Laboratory

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Georgia Institute of Technology

ENGINEERING EXPERIMENT STATION

ATLANTA, GEORGIA 30332

3 March 1980

Warner Robins Air Logistics Center
Robins Air Force Base
Georgia 31098

ATTENTION: Mr. Robert E. Webb

REFERENCE: F09603-78-G-4368 Order No. 0004
GA Tech Project No. A-2259

SUBJECT: Monthly Status Report No. 17
(February 1980)

Gentlemen:

A summary of the progress on the reference contract for the period 1 February 1980 to 29 February 1980 is contained herein.

The purpose of this effort is to restructure the AN/ALR-46 software module Emitter Trackfile Entry (ETE) using structured programming techniques to enhance the maintainability of the software, and to determine the extent to which this restructuring degrades the performance of the module.

Summary of Technical Efforts

Technical efforts have been minimized due to lack of funds. A low level of effort has been devoted to coding and testing.

Expenditures

The expenditures through 31 January 1980 were \$51,891. The estimated expenditures for February 1980 are \$800 bringing the estimated total expenditures through February to \$52,691. The project ceiling price is \$45,000 leaving a deficit of \$7,691.04 as of 29 February 1980. A request for additional funding in the amount of \$12,000 was submitted to WR-ALC on 17 January 1980.

Monthly Status Report No. 17
Contract No. F09603-78-G-4368-0004
GA Tech Project No. A-2259

3 March 1980

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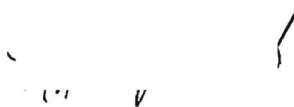
Schedule

Approximately two months are required to complete the project. This estimate assumes six weeks to complete the coding and validation and the comparative test plan, which will be pursued in parallel, followed by two weeks to perform the testing and complete the Final Engineering Report. A specific schedule will be submitted when technical efforts resume.


Future Work

When resumed, efforts will be directed primarily toward completion of coding and validation. Development of the comparative test data will be pursued in parallel.

Respectfully submitted,


M. A. Lipscomb
Project Director

APPROVED:


T. M. Miller, Jr., Chief
Defense Systems Division
Systems Engineering Laboratory

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Georgia Institute of Technology

ENGINEERING EXPERIMENT STATION

ATLANTA, GEORGIA 30332

7 April 1980

Warner Robins Air Logistics Center
Robins Air Force Base
Georgia 31098

ATTENTION: Mr. Robert E. Webb

REFERENCE: F09603-78-G-4368 Order No. 0004
ETE Restructuring Task
GA Tech Project No. A-2259

SUBJECT: Monthly Status Report No. 18
(March 1980)

Gentlemen:

A summary of the progress on the reference contract for the period 1 March 1980 to 31 March 1980 is contained herein.

Objective

The purpose of this effort is to restructure the AN/ALR-46 software module Emitter Trackfile Entry (ETE) using structured programming techniques to enhance the maintainability of the software, and to determine the extent to which this restructuring degrades the performance of the module.

Summary of Technical Efforts

Coding and validation of the ETE module were completed in March. Efforts were also devoted to the formulation of Restructuring Procedures, and the compilation of test data for the comparative testing.

Documentation

Technical Memoranda

Technical memoranda are prepared by members of the project team for internal use in the communication and documentation of results and procedures. The following technical memoranda were produced in March.

<u>Number</u>	<u>Title</u>
TM-2259-13	Production of the New Code - An Overview of Goals and Procedures
TM-2259-14	Design Procedures
TM-2259-15	Coding and Validation Procedures

Effort Expended

The following table lists efforts expended, in man-hours, for the month of March.

<u>Professional Personnel</u>	<u>Man-Hours</u>
Miller, T. M. Senior Research Engineer	2
Ballentine, Michael Graduate Res. Assistant	48
Snow, Al Student Assistant	101

Expenditures

The total of expenditures through 29 February 1980 was \$52,824. The project ceiling price is \$45,000 leaving a deficit of \$7,824. Additional funding in the amount of \$12,000 was received in March under Contract No. F09603-78-G-4368-0015. Since the additional funding was received under a separate order number, separate budgets will be maintained. The current deficit on Order No. 0004, however, reflects expenditures for personal services provided for in the Statement of Work accompanying Order No. 0015. Thus the budgets will be adjusted to remove the personal services and related deficits from Order No. 0004.

Meetings

Andy Lipscomb of Georgia Tech met with Harry Jennings of WR/ALC on March 26, 1980 to discuss the availability of WR/ALC computing facilities for tasks related to the comparative testing and to determine a revised schedule for the remainder of the program. The principle results of the meeting were as follows:

The WR/ALC ECLIPSE computer will be available to Georgia Tech personnel from 1:00 to 9:00 pm on April 4, 1980. At this time, GA Tech personnel will attempt to run all the driver software which has been developed for the comparative testing in order to determine the nature and scope of any incompatibilities which may exist between the software and the computer. The ECLIPSE will be available again from 4:00 to 10:00 pm on April 28 through May 2 for dedicated use by Tech personnel in the comparative testing.

Monthly Status Report No. 18
Contract No. F09603-78-G-4368-0004
March 1980

7 April 1980

Page 3

In April, Tech will deliver final versions of the Design Specification and Test Plan. Tech will also provide Mr. Jennings with draft versions of the Restructuring Procedures, and level of effort figures for the project. Final versions of the Restructuring Procedures and level of effort figures, together with the results of the testing, will be documented in the Final Engineering Report, which will be delivered by May 30, 1980.

Schedule

See "Meetings" Above.

Future Work

Technical efforts in April will be devoted to:

1. Compatibility test
2. Completion of the Restructuring Procedures
3. Completion of the Test Plan
4. Comparative Testing

Respectfully submitted,

M. A. Lipscomb
Project Director

APPROVED:

T. M. Miller, Jr., Chief
Defense Systems Division
Systems Engineering Laboratory

tas

Enclosure



Georgia Institute of Technology

ENGINEERING EXPERIMENT STATION

ATLANTA, GEORGIA 30332

6 May 1980

Warner Robins Air Logistics Center
Robins Air Force Base
Georgia 31098

ATTENTION: Mr. Robert E. Webb

REFERENCE: F09603-78-G-4368 Order No. 0004
ETE Restructuring Task
GA Tech Project No. A-2259

SUBJECT: Monthly Status Report No. 19
(April 1980)

Gentlemen:

A summary of the progress on the reference contract for the period 1 April 1980 to 30 April 1980 is contained herein.

Objective

The purpose of this effort is to restructure the AN/ALR-46 software module Emitter Trackfile Entry (ETE) using structured programming techniques to enhance the maintainability of the software, and to determine the extent to which this restructuring degrades the performance of the module.

Summary of Technical Efforts

Technical efforts in April were devoted to the following items:

1. The Driver Software Compatibility Test
2. The Test Plan
3. The Restructuring Procedures
4. The Comparative Testing

The first three items were completed. The Comparative Testing was begun, but not completed; progress on this item is described under "Meetings" below.

Documentation

Technical Memoranda

Technical memoranda are prepared by members of the project team for internal use in the communication and documentation of results and procedures. The following technical memoranda were produced in April.

Number

Title

TM-2259-16

Summary of Efforts on the ETE
Restructuring Task

Effort Expended

As described in the previous Monthly Status Report (No. 18) a separate contract (No. F09603-78-G-0015, GA Tech Project No. A-2606) has been provided for the Comparative Testing, and the development of the Restructuring Procedures. All efforts are currently being charged to that project.

Meetings

Andrew Lipscomb, Michael Ballentine, and Beth Cockerham of Georgia Tech traveled to WR/ALC on April 4, 1980 to conduct the Driver Software Compatibility Test. The Tech personnel met first with Harry Jennings of WR/ALC and delivered a draft copy of the Test Plan for WR/ALC review, then proceeded to the Compatibility Test with Bill Calkins of WR/ALC in attendance. The Tech personnel successfully brought up the driver in the configuration used for testing the restructured version of ETE and executed several tests, indicating that the main portion of the driver and all supporting software were compatible with the WR/ALC computer. Time did not permit reconfiguration of the driver for the original version of ETE.

Andrew Lipscomb and Beth Cockerham returned to WR/ALC for the week of April 28 through May 2, 1980 to conduct the Comparative Testing. At this time, a draft copy of the Restructuring Procedures, and preliminary figures on the effort expended in the project, broken down by task and by category of personnel were delivered to Harry Jennings.

Unexpected difficulties were encountered in the comparative testing. The test driver was reconfigured for the original version of ETE, and the ETE module was extracted from the ALR-46 OFP and assembled successfully with the driver. These tasks required approximately 3½ days. The assembled driver and ETE module failed to execute the test cases, however. The Tech personnel were unable to determine the source of the difficulty in the time remaining.

Schedule

Due to upcoming WR/ALC priority tasks, a second test session cannot be scheduled immediately. Tom Batterman and Bill Calkins of WR/ALC agreed to notify the Tech personnel at the earliest opportunity for a second session, probably sometime in mid May. Harry Jennings, the project technical monitor has been notified of this arrangement.

Monthly Status Report No. 19
Contract No. F09603-78-G-4368-0004
April 1980

6 May 1980
Page 3

Future Work

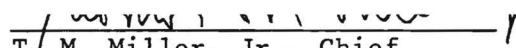
At this time, all contract deliverables except the Final Engineering Report have been completed, either in final form or as sponsor-approved drafts. Only the Comparative Test results are lacking in the technical data for the Final Engineering Report. The remaining technical work falls under the Statement of Work of Contract F09603-78-G-4368-0015, and progress will be reported in the Monthly Status Letters under that contract in the future.

Respectfully submitted,



M. A. Lipscomb
Project Director

APPROVED:


T. M. Miller, Jr., Chief
Defense Systems Division
Systems Engineering Laboratory

tas

Enclosure

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Atlanta, Georgia

CPCI Computer Program Development Specification
for the
Emitter Trackfile Entry Module
of the
ALR46 Operational Flight Program

By

M. Andrew Lipscomb

CONTRACT F09603-78-G-4368-0004

Performed for

WARNER ROBINS AIR LOGISTICS CENTER
Robins Air Force Base
Warner Robins, Georgia

FOREWORD

The Engineering Experiment Station of the Georgia Institute of Technology is pleased to present the CPCI Computer Program Development Specification (Part 1 Spec) for the Emitter Trackfile Entry (ETE) module of the ALR-46 Operational Flight Program. This document was prepared under Contract #F09603-78-G04368, Order No. 004 for the United States Air Force, Warner Robins Air Logistics Center, Robins Air Force Base, Georgia 31098. The document was prepared in contractor format with DI-E-30113, Computer Program Development Specification, used as a guide to content.

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1.0 OBJECTIVES

The software subject to this specification is a restructured version of the Emitter Trackfile Entry (ETE) module currently in use in the AN/ALR-46 Operational Flight Program (OFP), version V4. High maintainability is the primary design objective for the restructured ETE module; the restructured ETE module will be functionally equivalent to the ETE module currently in use in the V4 OFP, but it will incorporate features, such as structured code and sound modularity, to improve maintainability.

The objective of the restructuring effort is to evaluate changes in program efficiency (execution time and core utilization) resulting from the introduction of structured design features.

3.0 PRI DEINTERLEAVING

In each measurement cycle, a Time of Arrival (TOA) is determined for each of a number of radar pulses originating in a particular band and directional sector (each such group of pulses is referred to as a snapshot). The pulses may originate from several emitters. In order to determine the PRI of a particular emitter, it is necessary to separate, or deinterleave, the pulse train due to a particular emitter from the total set; this is the function of the PRI Deinterleave (PRIDE) routine in the ALR-46 OFP.

PRIDE is a highly complex procedure and will not be described here. Several characteristics of the deinterleave procedure are noteworthy, however, in that they lead to functional requirements in ETE. These characteristics, including the treatment of staggered pulsetrains and several cases of erroneous deinterleaving, will be discussed following a brief description of the basic techniques used in PRI deinterleaving. The material in this section is presented to aid in the understanding of ETE only, and it should not be construed as a functional description of the PRIDE routine.

3.1 Basic Techniques in PRI Deinterleaving

Two basic search techniques are used in PRI deinterleaving: binary search and sliding window search.

Binary search looks for repetitions in TOA differences. The technique is to determine the difference in TOA between the first and second pulses in the buffer and see if this TOA difference is repeated. If not, the difference between the first and third pulse is tried. The process is continued until a repeating TOA difference is found. The repeating TOA difference determines one pulse train and its PRI. This pulse train is removed from consideration (deinterleaved) and the entire procedure repeated for the remaining pulses. The procedure is illustrated in

Figure 1.

The sliding window search approach to deinterleaving depends on prior knowledge of the PRI's which may be expected to occur in the pulse set. For this reason, the PRIDE routine using sliding window search is referred to as "Informed" PRIDE. Rather than looking for repetitions of successive pulse TOA differences, informed PRIDE looks for repetitions of successive pulses at a specific PRI taken from the trackfile. The procedure is illustrated in Figure 2.

PRIDE attempts to extract stable pulsetrains first, then jittered pulsetrains. Both the binary and sliding window procedures employ a match window. This window specifies how far from the expected position a pulse can be and still be accepted as part of a pulsetrain. Note that if a narrow window is employed, jittered pulsetrains may not be deinterleaved. Conversely, if a wide window is used, an unrelated group of pulses may be erroneously deinterleaved as a pulsetrain (see Figure 3). PRIDE partially overcomes this difficulty by searching first with a narrow window, then, after all pulsetrains detectable with the narrow window have been deinterleaved, with a wide window. When the stable pulsetrains have been removed, the probability of erroneously deinterleaving an unrelated group of pulses is lessened. Deinterleaved pulsetrains are designated stable or jittered, depending on the window used in their detection -- narrow for stable pulsetrains, wide for jittered pulsetrains.

3.2 Staggered Pulsetrains

Staggered pulsetrains are pulsetrains having more than one PRI (see Figure 4). Such pulsetrains are deinterleaved into component pulsetrains, each with a single PRI (referred to as the fundamental or sum PRI), normally representing the smallest repeating interval in the pulsetrain, that is, the smallest interval detectable in a binary search deinterleave procedure. PRIDE does not

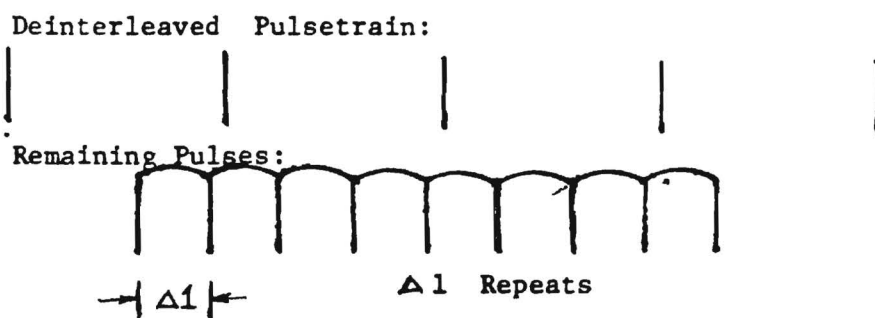
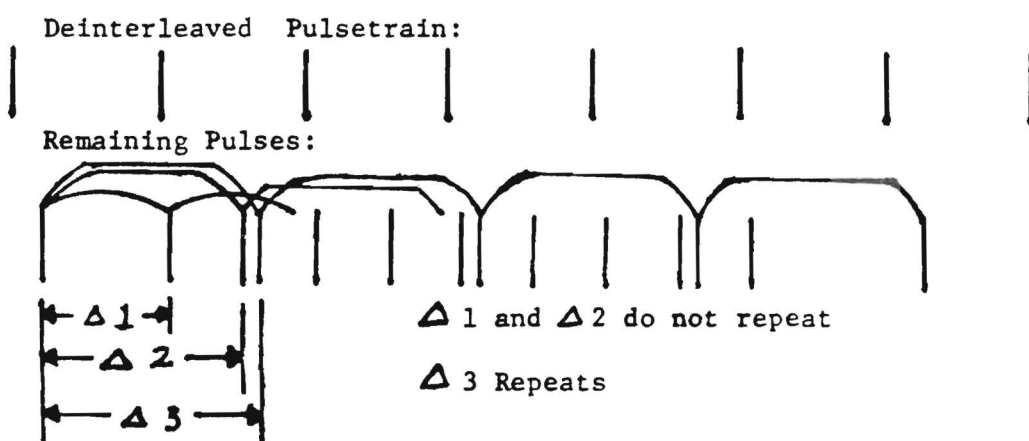
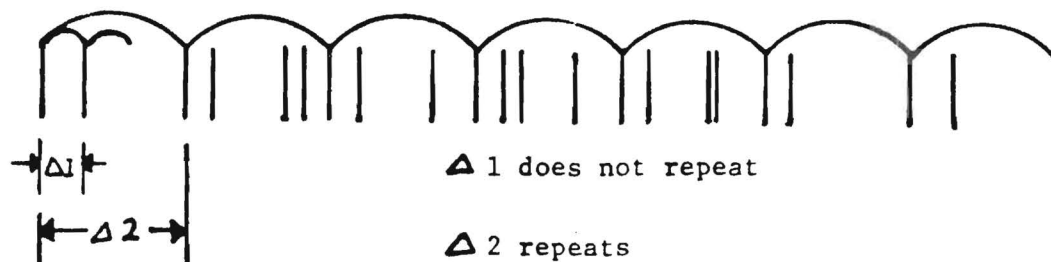
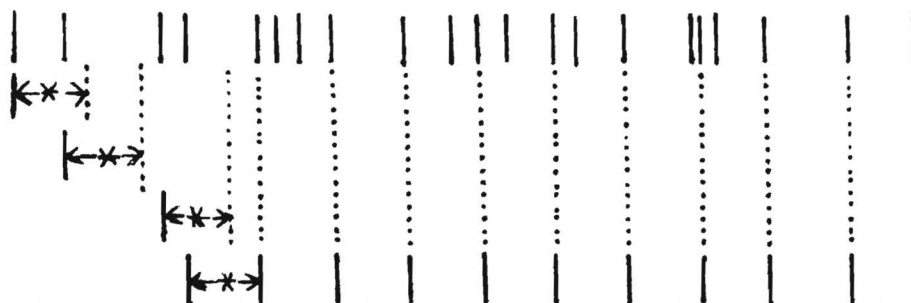


FIGURE 1. Binary Search PRI Deinterleaving

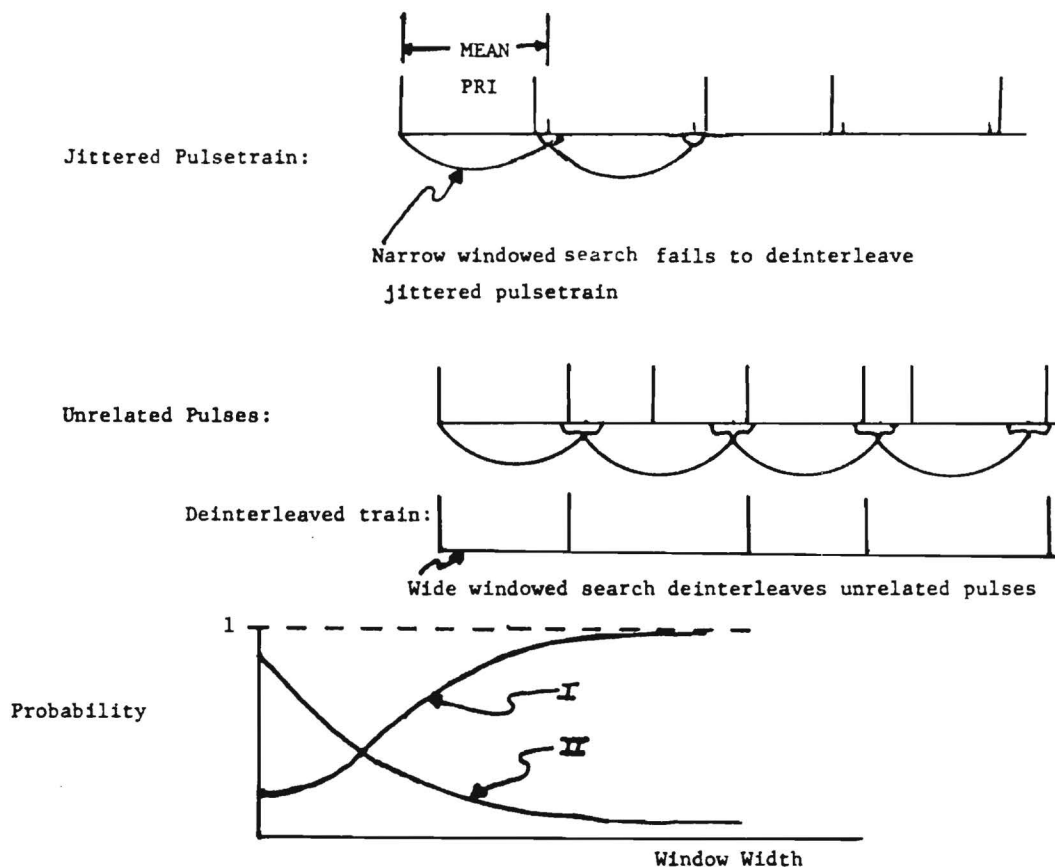


1st, 2nd, and 3rd pulses are not repeated
at the specified PRI

4th pulse is repeated

* Expected PRI

FIGURE 2. Sliding Window Search PRI Deinterleaving

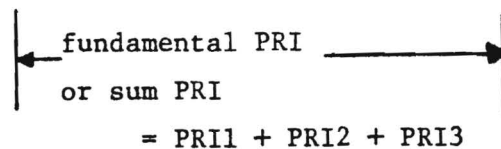


I represents the probability of erroneously deinterleaving unrelated pulses

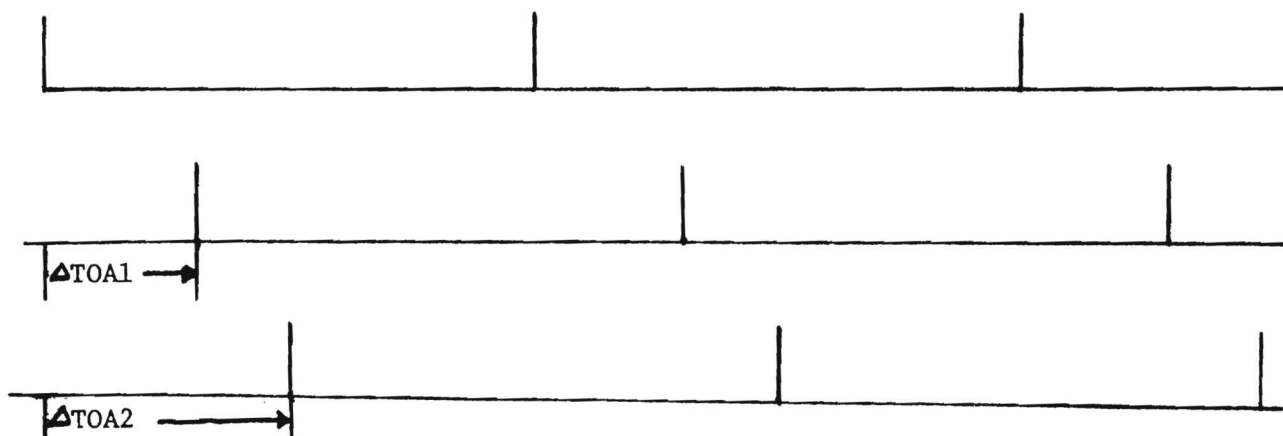
II represents the probability of failing to deinterleave a legitimate pulsetrain.

FIGURE 3. Potential Deinterleaving Errors Due to Window Width Used in PRIDE

Pulsetrain with 3-level stagger



PRIDE Deinterleaves:



$\Delta TOA < PRI$ for components of a staggered pulsetrain

FIGURE 4. Deinterleave of Staggered Pulsetrain

discriminate between pulsetrains deinterleaved from a single staggered emitter and pulsetrains from distinct emitters. Thus, a routine is included in ETE to detect staggered trains based on starting TOA differences (difference in TOA between the lead pulses) between trains with matching TOA and AOA. Note that for components of a staggered train, this TOA difference will be less than the PRI.

3.3 Erroneous Deinterleaves

Aside from the possible spurious deinterleaving of unrelated pulses mentioned in Section 3.1, there are a number of cases in which valid pulsetrains may be erroneously deinterleaved into component pulsetrains. Certain of these cases are described in the following sections.

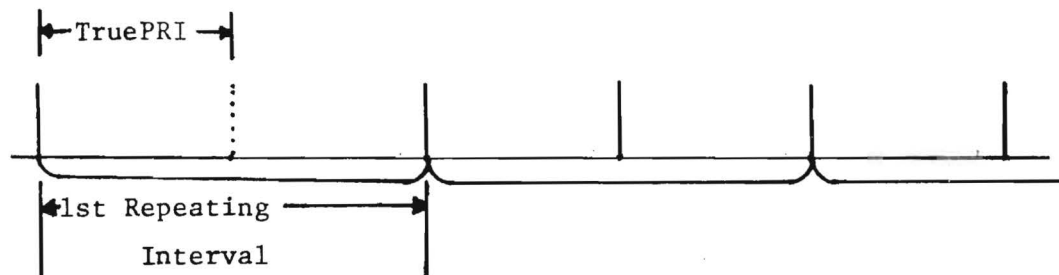
3.3.1 Missing Pulses

Due to a number of causes which need not be described here, one or more pulses in a pulsetrain may go undetected. As shown in Figure 5, missing pulses may cause a variety of erroneous deinterleaves depending on the number of missing pulses and their position in the pulsetrain. In this case, the error is originally due to the binary search algorithm. If, however, the error goes undetected and the erroneous PRI is later used in a sliding window search, the error will be propagated since pulses will be found at the expected interval. The key point here, as in many of the cases to follow, is that if pulses are repeated at a given interval, they will also be repeated at any integer multiple of that interval.

3.3.2 Harmonic PRI's

Pulsetrains with harmonic PRI's (that is, the PRI of one pulsetrain is an integer multiple of the PRI of the other) may be generated by the same emitter in different frequency bands or at different times. A potential deinterleave error

2nd pulse in pulsetrain missing:



Deinterleaved Trains:

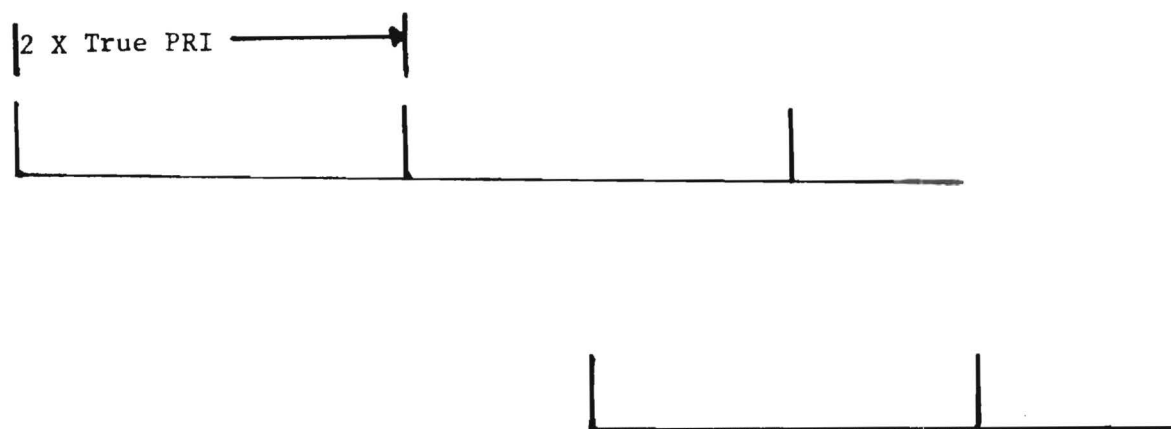


FIGURE 5. Erroneous Deinterleaves Due to Missing Pulses

arises when the pulsetrain with the longer PRI (the superharmonic) is detected first. If, after initial detection by a binary search, the superharmonic PRI is used in a sliding window search, the pulsetrain with the shorter (subharmonic) PRI may be deinterleaved into components. This situation is illustrated in Figure 6.

3.3.3 Stable-Jitter Crossovers

As described in Section 3.1, the PRIDE routine extracts stable pulsetrains from a snapshot first, using a narrow search window, then jittered pulsetrains using a wider search window. Certain emitters generate a pulsetrain with a degree of instability near the borderline of what is detectable as stable. The result is that in a series of snapshots, the pulsetrain may be deinterleaved randomly as either jittered or stable. Since the jitter condition is used in the ETE match routine, this switching affects the performance of ETE. Note that in this case, the pulsetrain is deinterleaved with the correct PRI; only the jitter condition is incorrect.

3.3.4 Pulse Frequency Modulation

Pulse Frequency Modulation (PFM) describes a pulsetrain in which the PRI varies in a controlled, regular fashion. Unlike true jitter, which is random change in the PRI resulting from hardware noise, PFM is an intentionally generated characteristic of a signal. PFM is usually sufficient to disallow detection of the pulsetrain as a whole as a stable train. Since PFM variations are regular, however, there may be one or more repeating intervals in the pulsetrain which are detectable in stable binary search. Thus, a deinterleave of a PFM signal may result in stable components with a superharmonic PRI and jittered components at the true PRI. Figure 7 provides an exemplary pulsetrain with PFM, and illustrates its deinterleave.

This pulsetrain detected first:



Subharmonic received later:



$$PRI2 = 1/2 PRI1$$

Sliding window search using PRI1 deinterleaves

subharmonic pulsetrain into components:

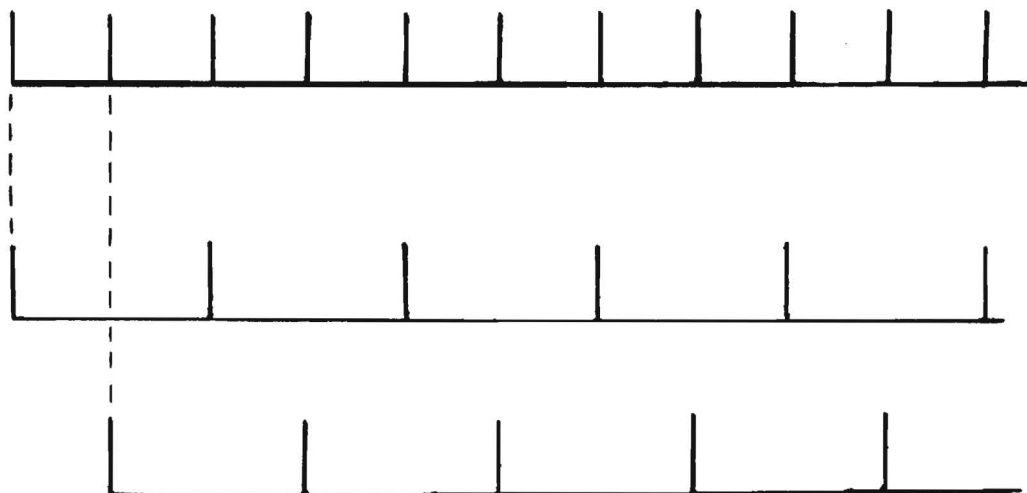
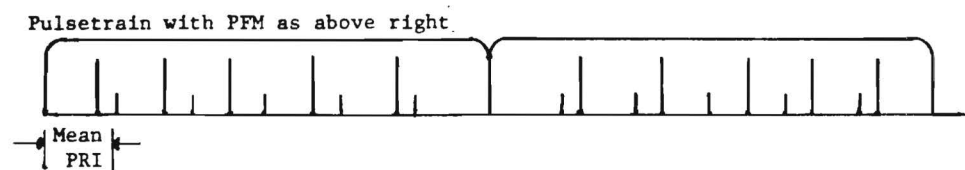
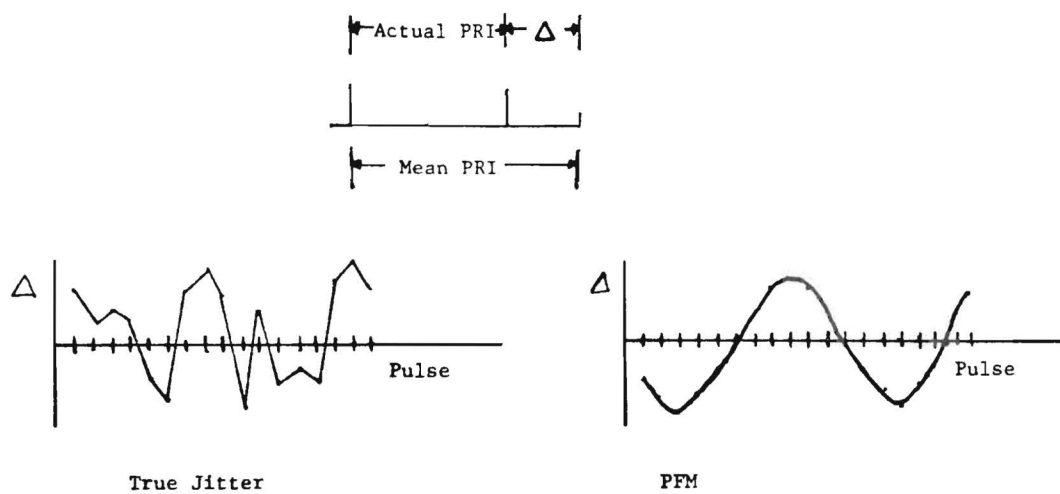


FIGURE 6. Erroneous Deinterleave Due to Harmonic PRI's



Deinterleave:

Stable -



Jittered -

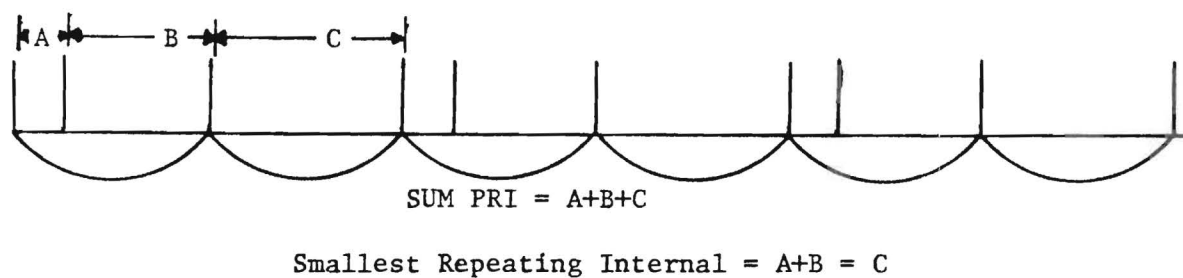


FIGURE 7. Erroneous Deinterleave of PFM Pulsetrain

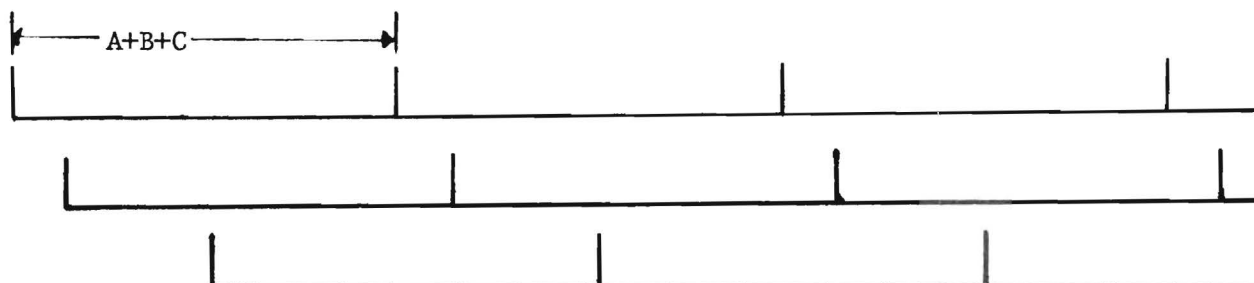
3.3.5 Harmonic Stagger

Harmonic Stagger describes a staggered pulsetrain in which the smallest repeating interval is less than the sum PRI. In the case of three level stagger with PRI's A, B, and C, for instance, such an instance occurs when $A + B = C$. A binary search deinterleave of such a pulsetrain may result in two harmonically related components rather than three components, each with the sum PRI. The situation is illustrated in Figure 8.

Harmonically Staggered Pulsetrain:



Desired Deinterleave.



Possible Binary Search Deinterleave

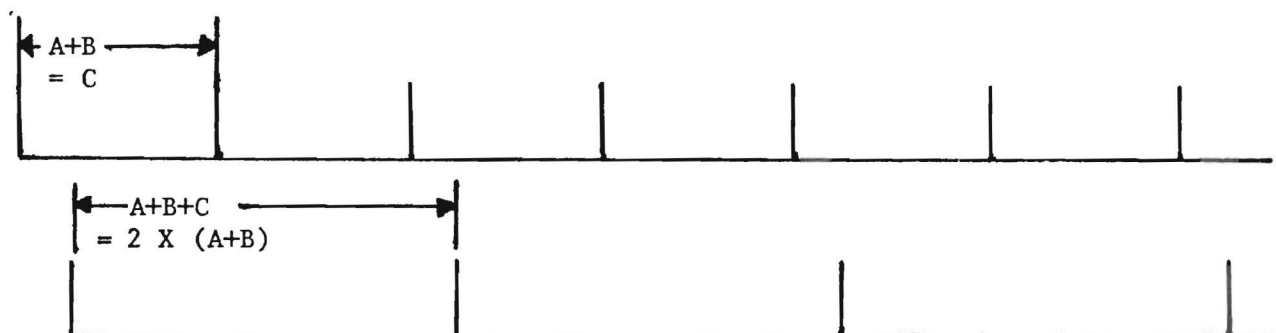


FIGURE 8. Erroneous Deinterleave Due to Harmonic Stagger

4.0 ETE DATA

Data accessed by ETE includes subsets of the EID file, which is the ALR-46 fixed data base, and various data sets which are created on-line in the course of a run.

4.1 EID File

The EID file is stored in Programmable Read Only Memory (PROM) and, thus, is not modifiable on line. The EID file contains threat data, that is, parameters used in threat identification and prioritization, and OFP Data, which includes a variety of parameters and flags used to control OFP execution.

The EID file is constructed so as to provide for limited reprogramming of the OFP without actual modifications to the code. The OFP may be tailored to a particular threat environment through the threat data; the processing logic may be modified through changes in the OFP Data.

4.1.1 Threat Data

The Threat Data accessed by ETE is contained in the Emitter TYPE table. The Emitter TYPE table is the most complex of the data structures accessed by ETE, but this complexity is not apparent in ETE's use of the table. The table consists of records, called TYPE sets, indexed by a variable called emitter TYPE. TYPE is, in fact, a variable, not a parameter, of the emitter. When first encountered, the emitter is assigned a TYPE. On successive intercepts of the emitter, as additional descriptive information is acquired, TYPE is changed to make use of the new information. Normally, as TYPE evolves in successive intercepts, the associated TYPE set becomes more specific with respect to emitter parameters. In effect, then, the Emitter TYPE table constitutes a decision tree rather than a simple tabulation of emitter data.

The complexity of the EID structure is not apparent in ETE's use of the table because, normally, the TYPE stored for an emitter in the Emitter Trackfile does not change in the course of ETE processing. An exception occurs in case of an emitter which generates pulsetrains at several distinct, but harmonically related, PRI's as described in Section 3.3.2.

The data elements contained in the TYPE set are described in the appendix to this document, Section A.1.

The Emitter TYPE table is accessed by routines outside of ETE. Thus, the structure of the table, both the arrangement of records and the arrangement of fields within records, shall be preserved in the restructured version of ETE.

4.1.2 OFP Data

The OFP data of significance to ETE consists of a number of data structures, each of which is accessed exclusively by a particular subroutine of ETE. The data may include parameters of the algorithm implemented by the subroutine and flags allowing selected portions of the subroutine to be disabled. Thus the subroutine may be reprogrammed, to a limited degree, through changes in the data. Most data structures also include features to partially overcome the difficulties of making such data changes in PROM.

Detailed descriptions of the data contained in the OFP Data Structures will be provided with the specification of the subroutine in which the data is used.

The OFP data for the restructured ETE subroutine shall preserve all reprogrammability features provided in the original version. Since the OFP data is routine specific, there is no requirement to preserve the structure of the data; the data structure will be preserved, however, unless there is a specific engineering advantage to be gained from a change. The data structures shall include features to facilitate data changes in PROM.

4.2 On-Line Data

Data produced on-line and used by ETE is stored in either the first 128 locations of the processor memory (page 0) or the Emitter Trackfile (all other memory used by ETE is PROM).

4.2.1 Page 0

Data in page 0 is directly accessible by assembly language load and store instructions, and no formal table structure is maintained. It is convenient, however, to distinguish two functional subdivisions in the data: Page 0 Control and Temporary File. Page 0 Control is used for the communication of control information between ETE and other modules in the OFP. The Temporary File contains measured characteristics of the emitter. Both data sets are described further in the Appendix, Sections A.2 and A.3.

4.2.2 Emitter Trackfile

All emitter specific data is stored in the Emitter Trackfile. This includes measured parameters of the emitter, priority information, display information, and processing control information. The portions of the Emitter Trackfile relevant to ETE are described in the appendix, Section A.4.

5.0 ETE SPECIFICATION

The remainder of this document specifies the ETE processing logic. ETE has two primary functional subdivisions: the match section and the update section. The match section is specified first, beginning in Section 5.1. The specification for the update section begins in Section 5.2.

5.1 Match Section

When data is collected for an emitter, the immediate task of ETE is to determine if the data originated from a previously undetected emitter, or one currently in the trackfile. To do so, the measured parameters of the emitter are compared to parameters recorded in the trackfile. Parameters available to ETE include band, PRI, directional sine and cosine (which, together, determine angle of arrival), emitter type, and a flag (JTFLG) indicating whether the emitter PRI is jittered or stable.

In the remainder of this specification, it will be useful to adopt a convention by which measured parameters may be distinguished from parameters carried in the trackfile. In keeping with usage in the ETE code, measured parameters will be prefixed with the letter P - PTYPE, PBAND, PPRI, etc. - and trackfile parameters will be prefixed with the letter E - ETYPE, EBAND, EPRI, etc.

5.1.1 Basic Concepts of Matching

There are thirteen distinct match routines in ETE. These routines have a number of common features which will be described here, following a discussion of the methods used in determining angle of arrival (AOA). Particular routines are specified beginning in Section 5.1.2.

5.1.1.1 Angle of Arrival Determination

The raw sine and cosine values, which together determine AOA, provided to ETE for emitters in bands 1, 2 and 3 are not true sine and cosine values. True sine and cosine values must be determined for accurate angle matching.

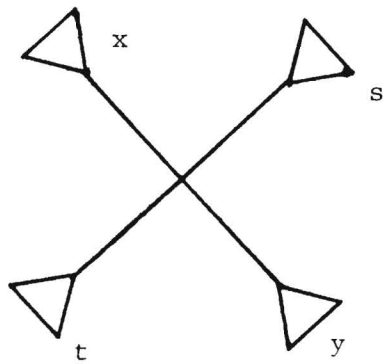
The directional data provided in bands 1, 2 and 3 is collected from four directional receivers mounted on two orthogonal axes. The raw sine and cosine values represent the ratios of received power level in opposing pairs (see Figure 9). In ETE, these raw values are replaced with true sin and cosine values taken from a stored table. The procedure is called sine-cosine normalization.

A difficulty arises in that, due to hardware limitations, accurate directional data cannot be determined if the emitter is far out of the plane of the receivers (also illustrated in Figure 9). This situation is indicated when both the raw sin and cosine values are near unity. This can be seen by noting that an emitter directly above or below the receiver set will produce equal power in all receivers. The raw sine and cosine values are scaled for ease of computation so that actual ratios are not used. The midpoint of the scale represents a ratio of one, indicating equal power in opposing receivers.

No match is attempted for pulse trains originating in the zone for which accurate AOA determination is impossible.

5.1.1.2 Match Criteria

BAND, AOA (as determined from the measured SIN and COS parameters) and PRI are the emitter parameters which determine an emitter match. A BAND match is successful if the BAND of the P-emitter (newly intercepted) is an allowable band for the E-emitter (in trackfile) as specified by the band parameters of the TYPE set corresponding to ETYPE. The E-emitter need not have been previously detected in PBAND, since a given emitter may generate beams in several bands.



x, y, s, and t represent the power level in each receiver.

$$\text{raw sine} = x/y$$

$$\text{raw cosine} = s/t$$

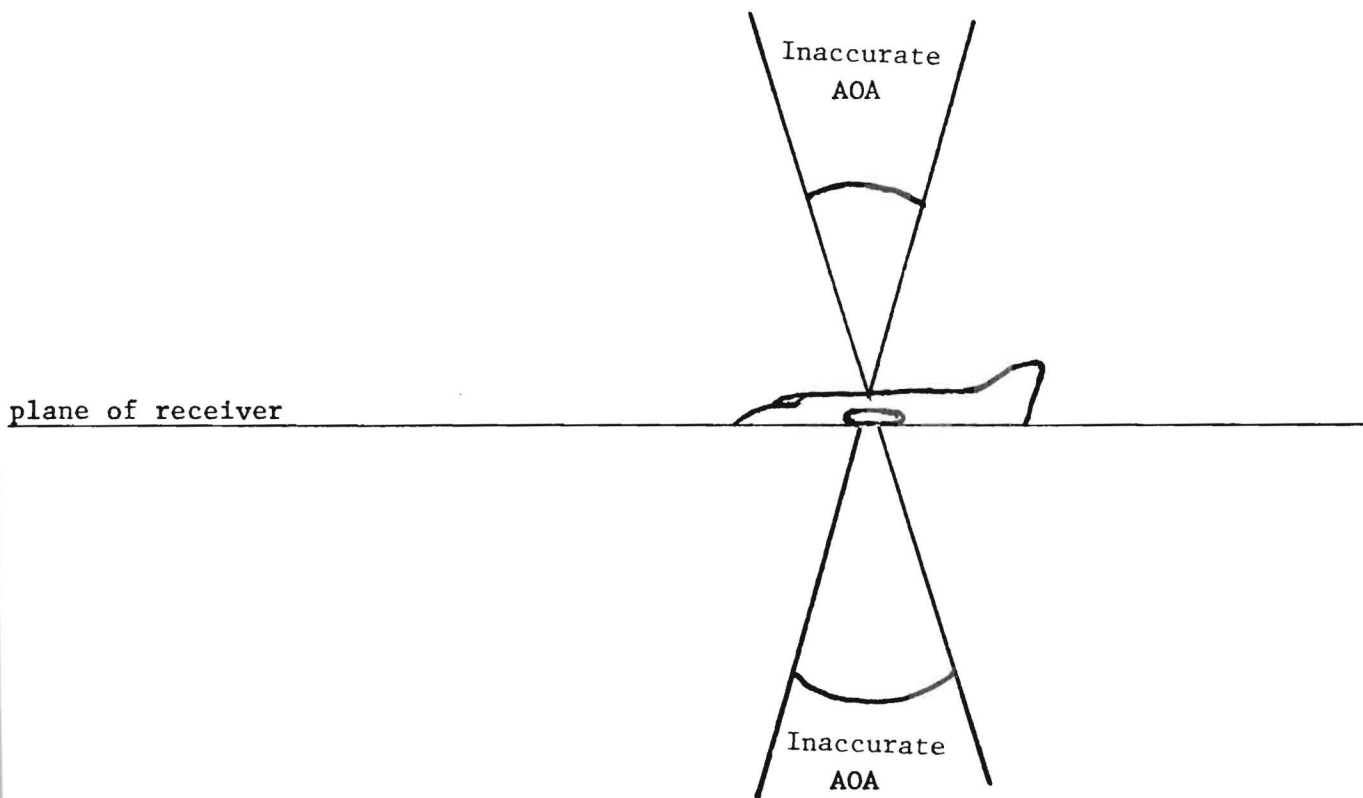


FIGURE 9. Angle of Arrival Determination

AOA and PRI matches use match windows which specify the maximum discrepancy allowable between the emitters for a match to be achieved (see Figure 10). The sizes of the windows are different for each match routine. An emitter match requires a match on all three criteria.

The BAND match is a simple yes-no criteria. AOA and PRI matches are more complex due to the freedom allowed in window selection. Generally, PRI is considered the more reliable match indicator. Thus, most match routines use a wide AOA window and a narrow PRI window.

PRI matching is complicated by the presence of multiple, harmonically related pulsetrains originating from a single emitter. In most match routines, a failure in the normal match described above results in an attempt at a harmonic match. In harmonic matching, the difference between the larger PRI and successive multiples of the smaller PRI is compared to the match window. The match window may be incremented by a fixed amount with each successive multiple of the smaller PRI to allow for error build-up resulting from the multiplication. The match criteria then is:

$$LPRI - (n+1) * SPRI \quad (\text{window} + n * \text{increment})$$

where LPRI and SPRI are the larger and smaller PRI's. The match attempt terminates unsuccessfully when the multiple of SPRI exceeds LPRI without a match.

5.1.1.3 Arrangement of Match Routines

The selection of a proper match windows for accurate emitter matching is subject to a difficulty similar to that described in Section 3.1 for PRI deinterleave window selection: if the window is too small, valid matches will fail; if too large, spurious matches occur. To compensate for this difficulty, the match section does matching in four rounds, that is, four passes through the trackfile, each using

Emitter match requires that:

1) PBAND appear in the ETYPE SET BAND word

2) $|PAOA - EAOA| < AOA \text{ window}$

3) $|PPRI - EPRI| < PRI \text{ window}$

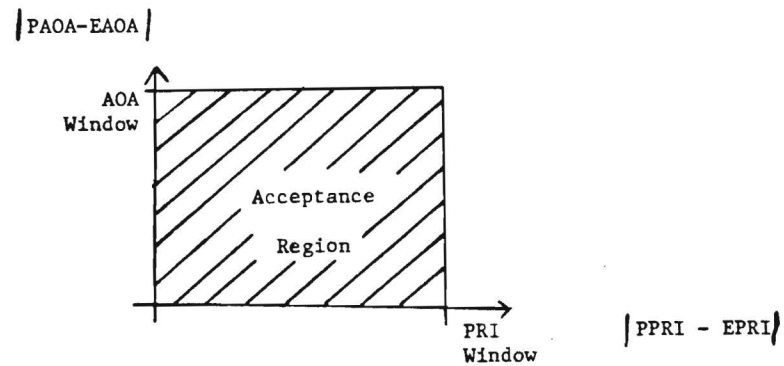


FIGURE 10. Emitter Match Criteria

successively less stringent match criteria. In the first 3 rounds, referred to as Round 0, 1, and 2, the PRI window is relaxed. In the fourth round, referred to as UNSTA since it is most effective in matching emitters characterized by PRI instability, the PRI window is relaxed, and the AOA window is contracted so as to keep their product (and thus the area of the acceptance region for each pair - see Figure 11) constant.

The match section is further refined by including distinct match routines for distinct combinations of round, and jitter conditions, with differing match criteria for each such routine, and by allowing no match at all for some combinations of these parameters. Allowed combinations, and the match criteria used in each, are described in detail beginning in Section 5.1.2.3.

5.1.1.4 Choice of Update Routine

A trackfile update may or may not be indicated following a match. If an update is indicated, the update routine chosen depends on the type of match achieved - normal or harmonic.

Two principles guide the decision of whether or not to update the trackfile entry of the matched emitter: an entry should be updated no more than once per snapshot, and, in the case of a single emitter producing several harmonically related pulsetrains simultaneously, the trackfile entry should correspond to the pulsetrain with the smaller PRI. Thus, if multiple pulsetrains are matched to trackfile entry in one snapshot, as may happen for a deinterleaved staggered pulsetrain as described in Section 3.2 or for any of the deinterleave errors described in Section 3.3.1, only the first match results in an update. The rest are ignored. Similarly, harmonic matches are ignored if PPRI is greater than EPRI.

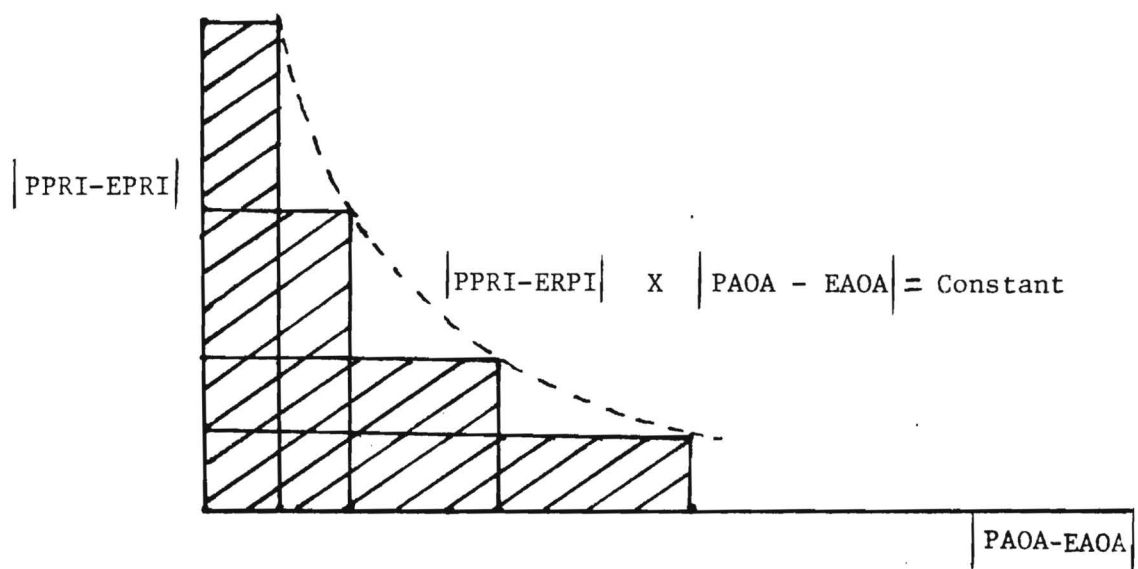


FIGURE 11. UNSTA Match Acceptance Region.

5.1.1.5 Typical Match Routine

A Warnier-Orr chart depicting typical match routine logic is provided in Figure 12. The match routines used in ETE will be specified, beginning in Section 5.1.2.3 in terms of variations relative to this typical routine.

5.1.2 Specification of the Match Section

Specifications for the principal subroutines of the match section follow.

5.1.2.1 Top Level Organization

Matching shall be performed in four rounds or passes through the trackfile. In keeping with established conventions, these shall be referred to as Round 0, 1, and 2, and UNSTA. Normally, match attempts cease upon the first determination of an emitter match; the match criteria are dictated, at least in part, by the current round. Under certain special conditions (described in Section 5.1.2.9), a match may lead to some modification of the P-parameters and a continuation of the matching process. The variable MATCH is a flag used to indicate the existence of an emitter match which implies an exit from the match rounds.

Sine-cosine normalization, including checks for inaccurate directional data, shall precede the match attempts for P-emitters detected in Bands 1, 2 or 3. Sine-cosine normalization is not applicable to emitters detected in Band 0 where directional data is unavailable.

The top level organization of the match section (and, in fact, of ETE as a whole) is shown in Figure 13.

5.1.2.2 Sine-Cosine Normalization Subroutine

The sine cosine normalization (SCNRM) subroutine shall receive as input the

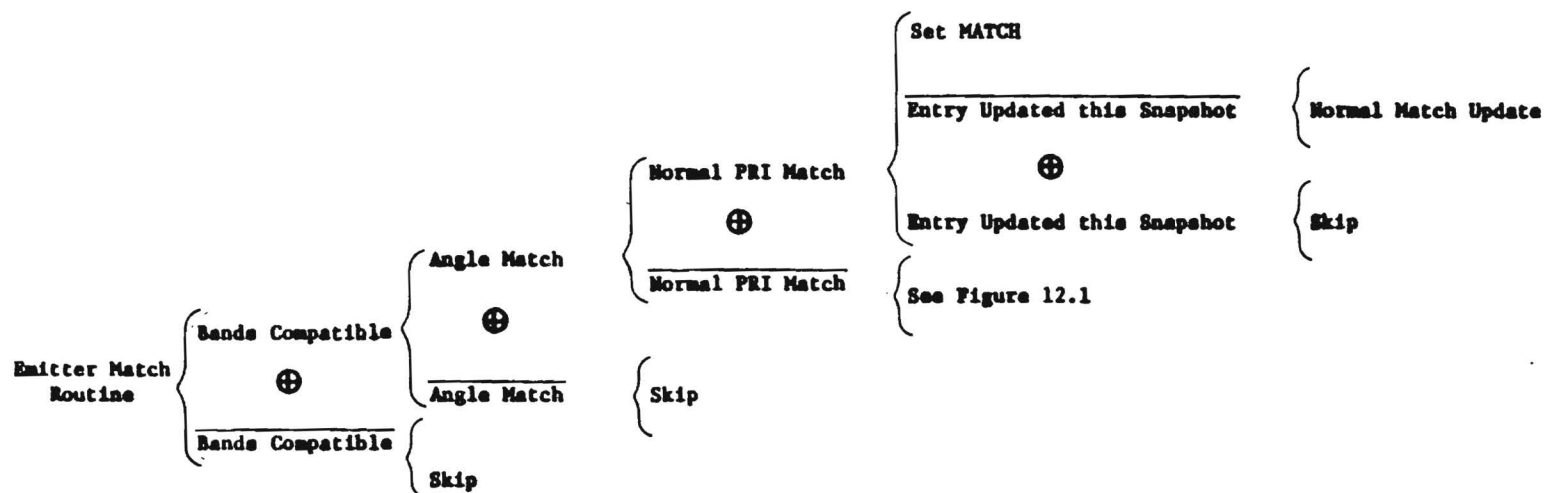
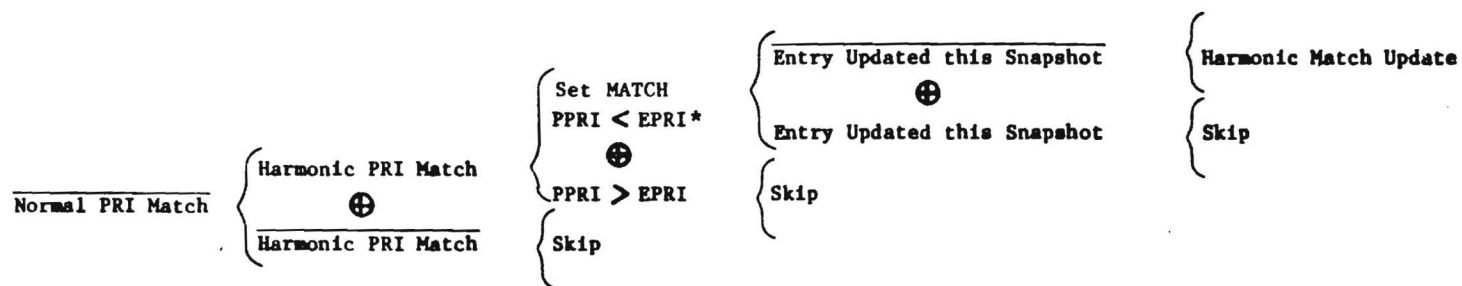


FIGURE 12. Typical Emitter Match Routine



* Case of equality excluded by the condition

Normal PRI Match

FIGURE 12.1 Typical Emitter Match Routine Continued

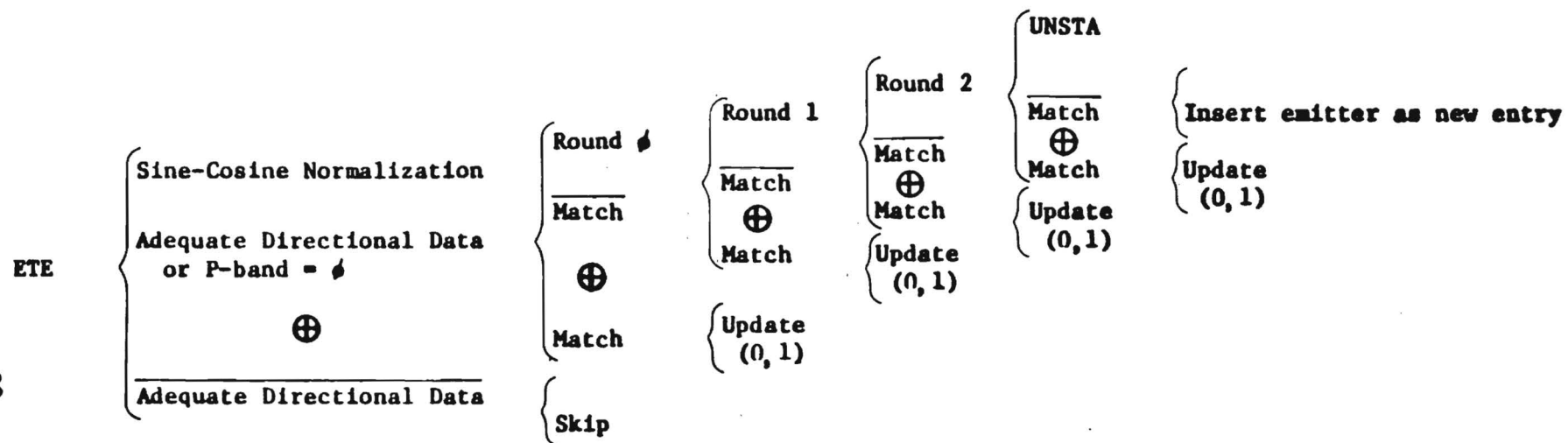


FIGURE 13. Match Section Top Level Organization

raw PSIN and PCOS values. SCNRM shall first determine if the values represent valid data, or if they fall into the rejection zone described in Section 5.1.1.1. The displacement of PSIN and PCOS from the midpoint of the sine/cosine scale (174 octal) shall be determined. PSIN and PCOS will be rejected if both displacements are less than a specified value SCMIN1 and the sum of the displacements is less than a second value SCMIN2. SCMIN1 and SCMIN2 shall be reprogrammable parameters stored in the EID file. If PSIN and PCOS are not rejected, the raw values will be replaced with normalized values taken from a locally stored table.

A Warnier-Orr diagram of SCNRM is provided in Figure 14.

5.1.2.3 Angle Match Subroutine

An angle match subroutine (AMTCH) shall be provided for used in all match routines. AMTCH shall receive as input the values PSIN, PCOS, PBAND, a match window (DELSC), and a pointer to the relevant trackfile entry. A match shall be allowed in either of the following cases:

Case 1 (Default Match):

$$PBAND = \emptyset \text{ or } EBAND = \emptyset$$

$$\begin{aligned} \text{Case 2: } & \left| PSIN - ESIN \right| < DELSC \quad \text{and} \\ & \left| PCOS - ECOS \right| < DELSC \quad \text{and} \\ & 8 \text{ Max } (\left| PSIN - ESIN \right| , \left| PCOS - ECOS \right|) + \\ & 3 * \text{Min } (\left| PSIN - ESIN \right| , \left| PCOS - ECOS \right|) < 8 * DELSC \end{aligned}$$

5.1.2.4 Harmonic PRI Match Subroutine

A harmonic PRI match subroutine (HRMCH) shall be provided for use in all harmonic match routines. HRMCH shall receive as input the smaller of the PRI's being compared (SPRI), the larger of the PRI being compared (LPRI), a match window WPRI, and an increment, INKR. A match shall be allowed if, for some

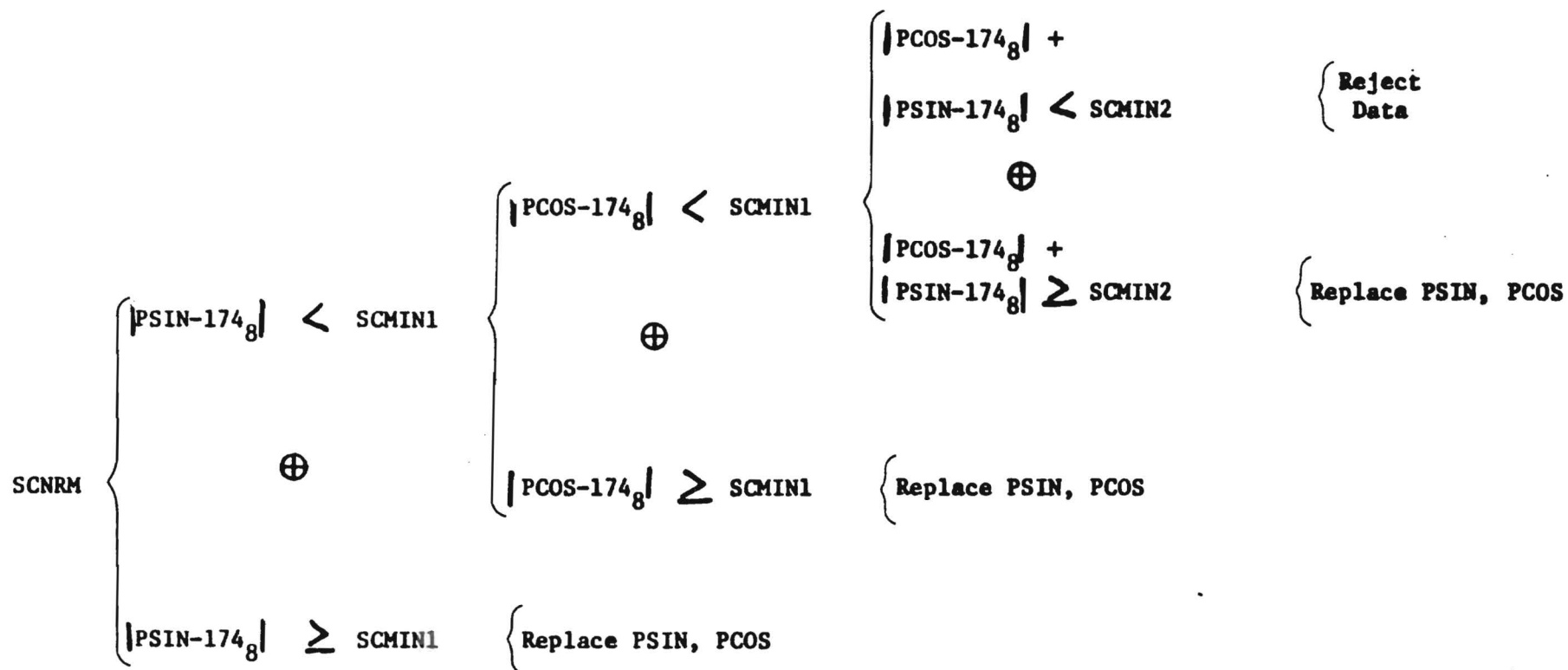


FIGURE 14. Warnier-Orr Diagram of Sine-Cosine Normalization Routine, SCNRM

integer, n:

$$| \text{LPRI} - (n+1)*\text{SPRI} | \leq \text{WPRI} + n*\text{INKR}$$

5.1.2.5 Match Routines - Round 0, 1, and 2

In Rounds 0, 1, and 2, match routines are selected on the basis of round and the combination of stable-jitter conditions in the two routines. All match routines in Round 0, 1, and 2 use the same angle match window, equivalent to 37° ; the match criteria differ in the PRI match window and, for harmonic match routines, the increment. The PRI window may be a default value, stored in the EID tables, a special TYPE associated value stored with the TYPE set, or an adaptive value computed in the UNSTA match routine on a previous match (adaptive PRI matching is discussed in Section 5.1.2.11 below). A match routine is not provided for every possible combination of round and jitter conditions.

The match section shall include match routines with PRI match criteria as shown in Table 1. The match routine nomenclature is as follows: the first character represents the type of match - N for normal, H for harmonic. The second character represents the Round - 0, 1, or 2. The third and fourth characters represent the jitter conditions of the P- and E-emitters, respectively.

The logic of most match routines is similar to that described in Section 5.1.1.4. The following sections specify variations to be incorporated in particular routines.

5.1.2.6 Conditions for Stagger Detection

As described in Section 3.2, staggered pulsetrains are deinterleaved into component pulsetrains at the sum PRI. Thus, the presence of several pulsetrains with equal PRI in the same snapshot, and consequent multiple matches to the same emitter, is evidence of stagger. If both the E- and P-emitter are stable (thus

TABLE 1. MATCH ROUTINES AND MATCH CRITERIA

<u>Match Routine</u>	<u>Window</u>	<u>Increment</u>
N 0 SS	Normal Default or Special (ETYPE)	N/A
N 0 JS	Normal Default or Special (ETYPE)	N/A
N 0 SJ	Normal Default or Special (PTYPE)	N/A
H 0 SS	Normal Default or Special (ETYPE)	same as window
H 0 SJ	Harmonic Default	same as window
H 0 JS	EPRI/16	zero
N1SS	Adaptive	N/A
N1SJ	Adaptive	N/A
N1JS	Adaptive	N/A
H1SS	Adaptive or EPRI/16	same as window
N2JJ	1/8 smaller PRI	N/A
H2JJ	1/8 smaller PRI	1

providing reliable data), the stagger level of the emitter may be determined by counting matches to the E-emitter within a snapshot. Thus, N~~Ø~~SS, instead of ignoring successive matches as is done in other routines, shall call a stagger detection routine, specified in Section 5.2.2.6, below, on each match following the initial match. A Warnier-Orr chart is provided in Figure 15.

5.1.2.7 Stagger Forgiveness

A Stagger Forgiveness routine shall be incorporated in H~~Ø~~SS to detect deinterleave errors resulting from harmonic stagger of the sort described in Section 3.3.5. Upon encountering conditions compatible with harmonic stagger, the Stagger Forgiveness routine shall compare PTYPE with entries in a table, stored in the EID files, of emitter TYPE's known to generate harmonic stagger. If PTYPE is found in the table, a Stagger Forgiveness bit shall be set for the matched emitter in the trackfile, and the PRI and stagger level corrected. The correct PRI and stagger level will be maintained in future intercepts by reference to the Stagger Forgiveness bit. Stagger Forgiveness may be deactivated by leaving the table of TYPE's empty.

5.1.2.8 Harmonic Forgiveness

As described in Sections 5.1.1.3 and 5.1.1.4, when an emitter generates harmonically related signals simultaneously in separate bands, the normal strategy is to maintain the subharmonic PRI in the trackfile and ignore intercepts of the superharmonic PRI. In certain cases, however, this strategy is unsatisfactory. One operational emitter, generating harmonically related signals, for instance, generates the subharmonic in Band Ø where directional data is unavailable; the superharmonic is, here, the better choice for entry in the trackfile. If, however, the superharmonic PRI is entered into the trackfile, a later deinterleave using a

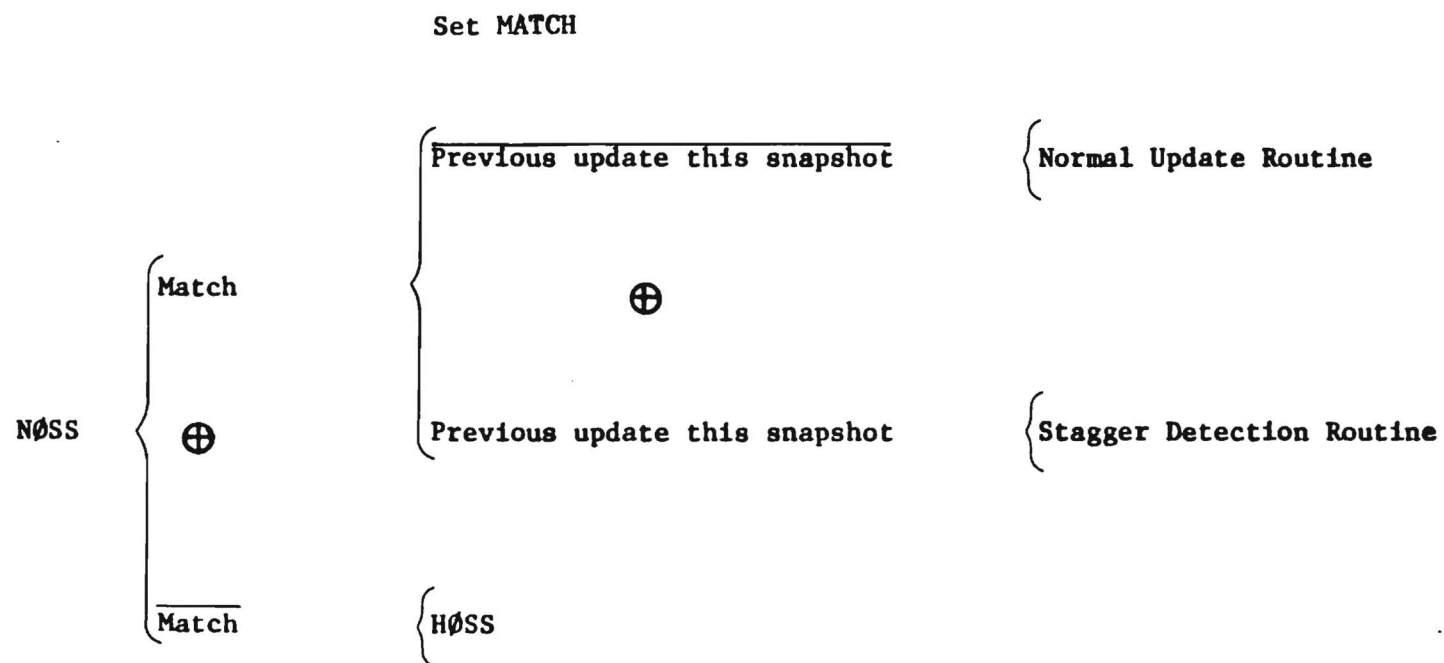


FIGURE 15. Conditions for Stagger Detection

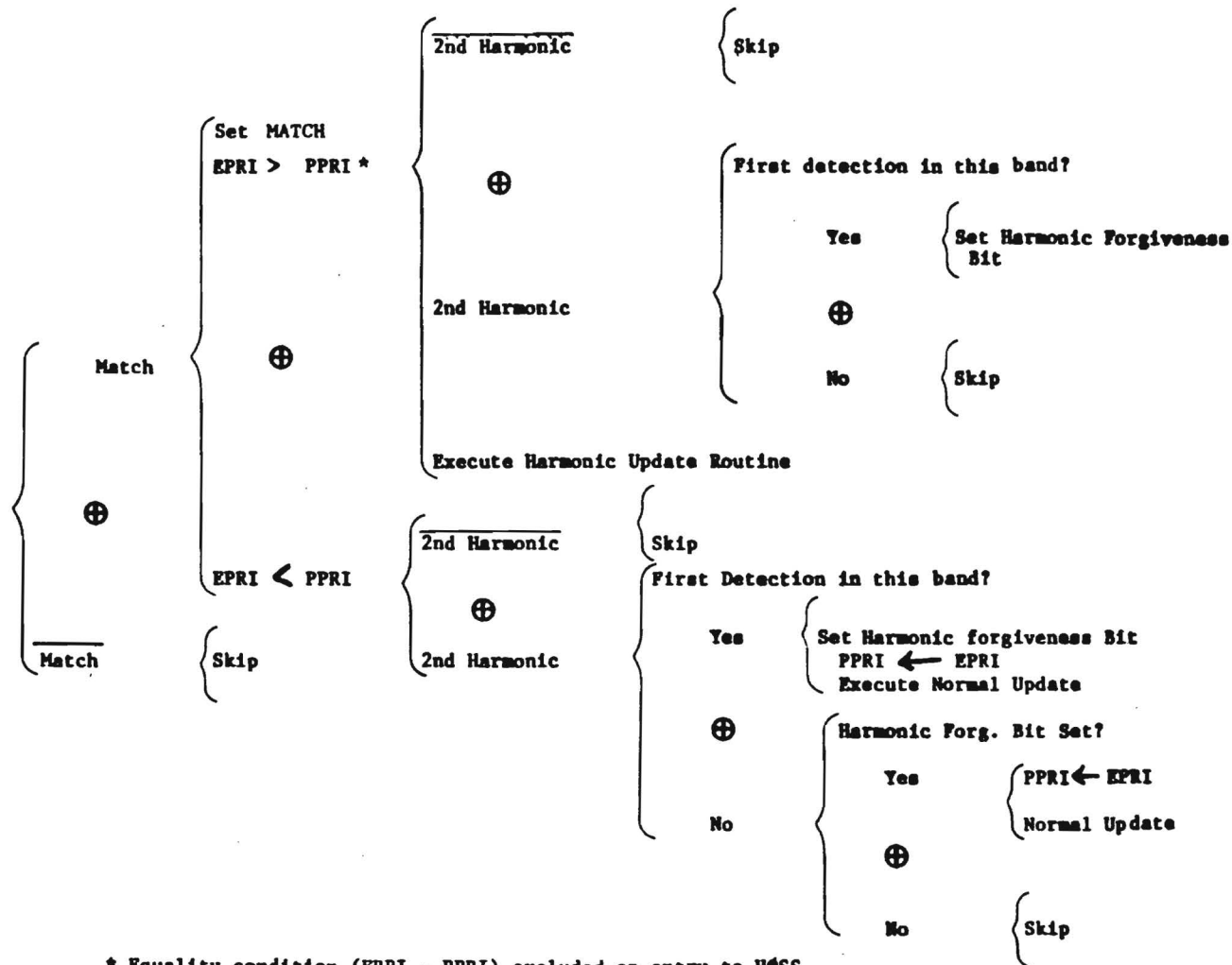
sliding window search based on the superharmonic PRI will lead to a deinterleave error as described in Section 3.3.2.

A Harmonic Forgiveness routine shall be incorporated into H~~0~~SS to cause a trackfile entry to be updated upon detection of a superharmonic while maintaining the subharmonic PRI in the trackfile. This shall be accomplished by substituting EPRI for PPRI and executing the normal (rather than harmonic) update routine. Harmonic Forgiveness shall be limited to second harmonics appearing in distinct bands. A Harmonic Forgiveness bit shall be set in the trackfile entry of an emitter having this characteristic. A flag shall be provided in the EID tables through which Harmonic Forgiveness can be disabled if desired. A Warnier-Orr chart of H~~0~~SS with Harmonic Forgiveness enabled (and Stagger Fogiveness disabled) is shown in Figure 16.

5.1.2.9 Stable-Jitter Match Combinations

Matches between pulsetrains, one of which is designated stable and the other jittered, may arise as a result of a stable-jitter crossover, as described in Section 3.3.3 or from a Pulse Frequency Modulated (PFM) pulsetrain, as described in Section 3.3.4. For a stable-jitter crossover, the PRI will be the same for both emitters (rather than harmonically related). Stable-jitter crossovers are of no consequence and no special handling is required. PFM pulsetrains, which may be deinterleaved into several harmonically related components, are potential sources of error, possibly generating multiple trackfile entries for a single emitter. H~~0~~SJ and H~~0~~JS, as implemented in the existing version of ETE, represent an experimental attempt to deal with the PFM problem. Since the attempt is less than totally successful, the motivation for these routines will not be described in detail here.

HØSS



* Equality condition (EPRI - PPRI) excluded on entry to HØSS.

FIGURE 16. HØSS with Harmonic Forgiveness Enabled

H0JS and H0SJ shall be implemented as in the original version of ETE. Warnier-Orr charts are provided in Figures 17 and 18.

5.1.2.10 PRI Averaging

In matches involving a jittered pulsetrain or an adaptive PRI match, or a PPRI shall be replaced with $(PPRI+EPRI)/2$ prior to entering the update routine.

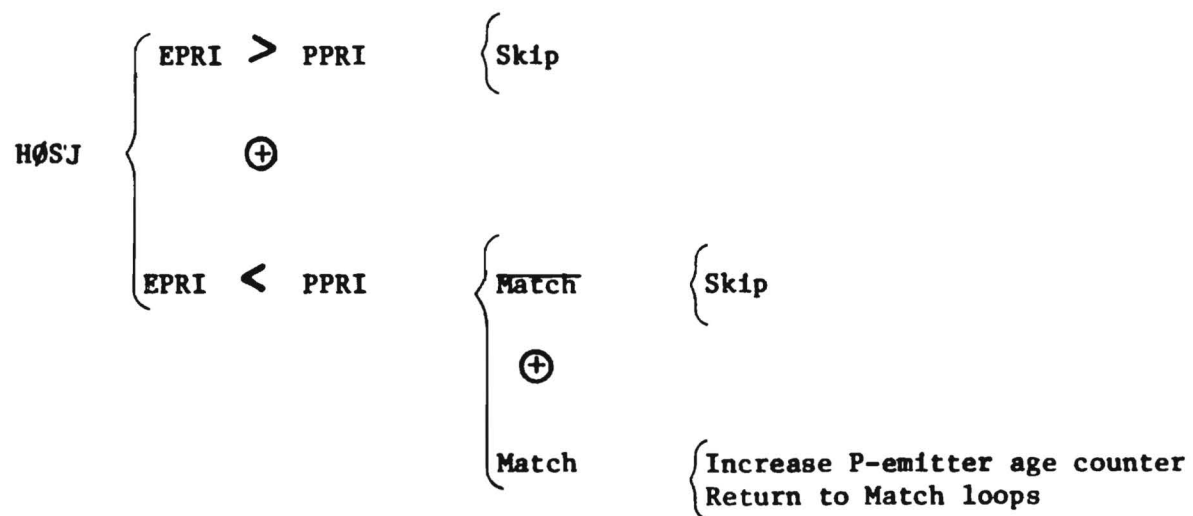
5.1.2.11 The UNSTA Match Routine and Adaptive Matching

Two sections of ETE are involved in adaptive matching: the UNSTA routine, and the Round 1 PRI matching routine. These two routines interface through the adaptive PRI window which is set in UNSTA following a match, and used in the Round 1 loop in subsequent PRI match attempts.

Adaptive matching is designed to maintain trackfile entries for emitters which evade the PRI matchloops due to long term (relative to the maximum snapshot duration of approximately 23 msec) PRI instability. Adaptive matching allows current information to be maintained for such emitters, and avoids the proliferation of spurious entries which would otherwise result from such PRI drift.

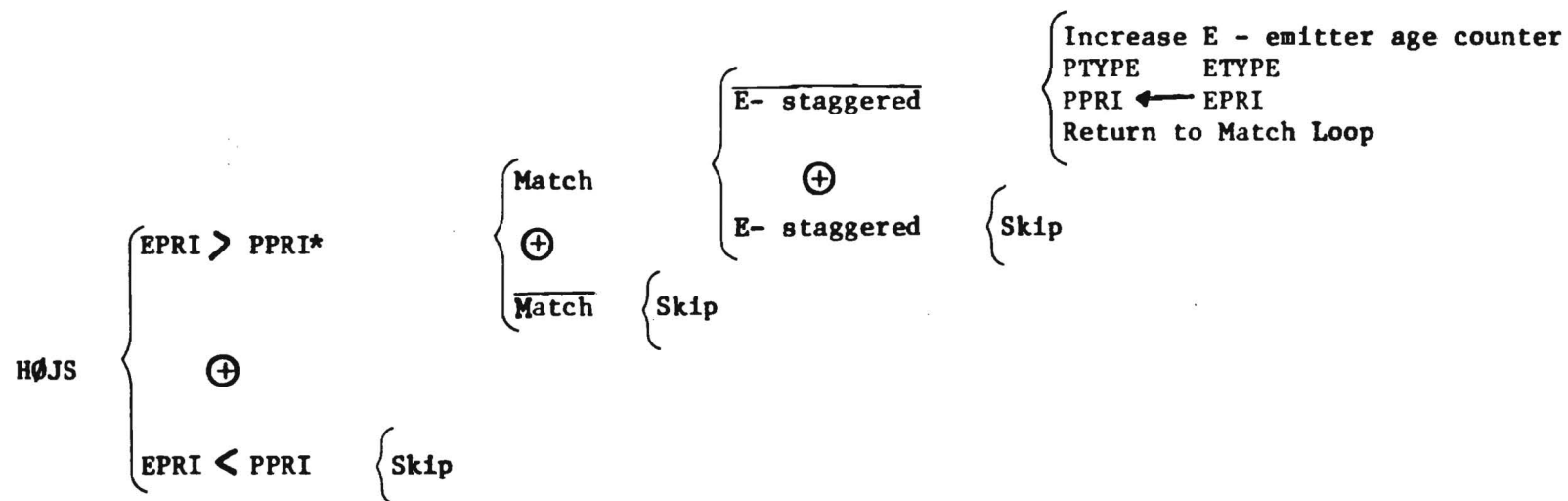
UNSTA shall check the P-emitter against successive entries in the trackfile, using the match criteria described in Section 5.1.1.1. If a match is achieved, UNSTA shall compute an adaptive match window which is equal to the PRI difference plus 300 n.s. or 6300 n.s., whichever is smaller. This adaptive match window shall be stored in the trackfile entry of the matched emitter.

The adaptive window computed by UNSTA is used in subsequent Round 1 PRI match attempts. When the emitter for which the window was computed is encountered again, a match will be achieved in Round 1 (thus avoiding the less efficient UNSTA routine) if the PRI drift has continued at a rate not greatly increased. Since use of the (typically large) adaptive window entails a substantial



* Equality condition (EPRI = PPRI) excluded on entry to HØSS.

Figure 17. Warnier-Orr Chart of HØSJ



* Equality condition (EPRI = PPRI) excluded on entry to HØJS.

Figure 18. Warnier-Orr Chart of HØJS

risk of allowing a spurious match, and since PRI drift is frequently a transient condition in which the PRI eventually reaches a stable mean value, the adaptive window is gradually tightened in Round 1. The window is decremented by 100 ns for each successful match, and EPRI is averaged with PPRI prior to entering the update section.

Since the match criteria of UNSTA are more susceptible to error than those of the PRI match routines, a number of additional checks shall be included prior to the match. These are:

1. Band Check - The E-emitter must have been previously detected in the band specified by PBAND. Note that this is more stringent than the band checks used previously.
2. TYPE disable setting - A bit in the TYPE set of the E-Emitter may be set to disallow an UNSTA match.
3. PRI Qualifying Check - A wide window PRI check is used to eliminate emitter pairs exhibiting a large discrepancy. The qualifying window may be a special, type associated window, a constant default window, or a fraction of EPRI, depending on the UNSTA Control Table settings (described below) and PTYPE.
4. ESTOA Check - The ESTOA check is the same as for other match routines, but here is performed prior to the match, thus possibly disallowing the match itself rather than the update only.
5. CEPC Check - CEPC is a trackfile variable indicating, nominally, the number of times the emitter must be intercepted before it is displayed. It is used here to indicate, essentially, the degree of confidence associated with the entry. UNSTA may require a high confidence entry indicated by $CEPC = 0$ (CEPC is initialized high and decremented on

successive intercepts). This test may be disabled through the UNSTA Control Table (described below).

An UNSTA Control Table shall be included in the EID files. The UNSTA Control Table shall contain reprogrammable parameters, including the PRI window-angle window pairs used for match criteria, and flags through which portions of the routine or the routine as a whole may be disabled. The UNSTA Control Table shall include separate sets of parameters to be selected based on PBAND - one set for Band 0 of the match section and one set for other bands. A Warnier-Orr chart is provided in Figure 19.

5.2 Update Section

The update section of ETE includes those routines which update or insert emitter trackfile entries following a match attempt. These are four such routines: one for update following the first harmonic match to a given emitter in a snapshot, one for update following the first normal match to a given emitter in a snapshot, one for update following successive normal matches in a snapshot, and one for the creation and insertion of a new record following a match.

5.2.1 Basic Concepts of Updating

Each trackfile entry contains data for three types: emitter input data, emitter TYPE dependent data, and internal data. Emitter input data includes all parameters which are taken from the Temporary file (see the Appendix, Section A.3); measured characteristics of the emitter, such as PRI and AOA, and flags such as the missile launch, missile alert, and pan receiver indicators are included. Emitter TYPE dependent data includes all parameters which are taken from the TYPE set of the emitter; portions of the priority word in the entry are included, for instance, as are initial values of certain portions of the internal data. The

internal data includes parameters which are maintained by ETE, and other routines, for purposes of internal control; emitter age parameters, the Candidate Emitter Promotion Count (CEPC), and flags, such as the band resolve request, which request execution of special routines are included.

Not all of the trackfile parameters will be described in detail in the specification (a summary description is provided in the appendix, Section A.4).

Several update routines are required, since not all of the information in a record is updated on every match. In the case of a normal match, the emitter input data and the internal data except for the stagger parameters are updated. In many cases of normal update, PTYPE is not substituted for ETYPE. In these cases, TYPE dependent data does not change.

Since TYPE is in part a function of PRI, the PTYPE corresponding to the subharmonic is substituted for ETYPE in a harmonic match. Thus, TYPE dependent data must be updated in the Harmonic Update, and the emitter input data must be updated. Internal data is not updated, since future normal matches and updates are expected.

A Normal or Harmonic Update of a given trackfile entry is performed no more than once per snapshot. Stagger detection requires two or more matches per snapshot. Thus, the Stagger Detection routine may, depending on match conditions, be called following matches other than the first in a snapshot to update stagger parameters.

Insertion of a new emitter entry requires insertion of the emitter input data and TYPE-dependent data, and initialization of the internal data.

5.2.1.1 Emitter Priority

The emitter priority word of the trackfile entry is a composite of fields indicating missile launch (ML), missile alert (MA), and panoramic receiver inter-

cept (PAN) conditions (provided as emitter input data), fixed priority (taken from the emitter TYPE set in the EID file), and measured power. When a priority update occurs, all fields are revised if either an ML, MA, or PAN condition is indicated. If none of these conditions exist, the remaining fields may be updated or zeroed, depending on the emitter TYPE and the current panel settings of the cockpit display. The priority is updated if the current TYPE is to be displayed, that is, if one of the following is true:

1. ETYPE is a known TYPE and is not a search radar
2. ETYPE is an unknown TYPE and the UNKNOWN button is pushed
3. ETYPE is a search TYPE and the SEARCH button is pushed

If none of these conditions exists, the priority is set to zero, effectively suppressing display.

5.2.1.2 Priority Order of the Trackfile

As described in Section 5.2.1.1, the priority word associated with trackfile entry is a composite of several fields representing both measured characteristics of the emitter and fixed data taken from the emitter TYPE set. Of these, the ML, MA, fixed priority, and power fields determine emitter priority. Since the trackfile is maintained in priority order, it must be reordered each time one or more of these fields is updated.

5.2.1.3 Adaptive Ageout

The trackfile parameters TTRAGE, CDAGE, and MLAG represent the time which has passed since the last match of the entry by an emitter in bands 1, 2, or 3 (where Threat Tracking Radars occur, hence TTRAGE), band 0 (CD band is band 0, hence CDAGE), or with a missile launch (hence MLAG) condition evident. These

parameters are set to zero in ETE when the relevant condition occurs, and incremented periodically by a routine outside ETE. Each time the parameters are incremented, their value is compared to an AGEOUT parameter taken from the emitter TYPE set. If the AGE parameter exceeds AGEOUT, the indicator of the relevant condition is removed from the trackfile. If both CDAGE and TTRAGE reach AGEOUT, the entry record is removed.

Nominally, the Candidate Emitter Promotion Count (CEPC) represents the number of times an emitter must be intercepted before it is displayed; it is used for other purposes, however, and generally represents the "confidence level" associated with an entry. CEPC is initialized to a value taken from the emitter TYPE set when the emitter entry is inserted into the trackfile and decremented each time the emitter is matched.

Occasionally, multiple entries may be inserted into the trackfile for a single emitter. The Adaptive Ageout routine is included in the update section to eliminate such spurious entries. Whenever CEPC becomes zero for any entry, that entry is compared to all other entries in the trackfile. If any entry exhibits band compatibility and close PRI correspondence, its age fields are set to one less than the ageout value. Thus, if the emitter is not matched in the next snapshot, it will be eliminated from the trackfile.

5.2.2 Specification of Update Section

The four principle update routines are specified below following specification of three subroutines of general applicability.

5.2.2.1 Display Decision Subroutine

A Display Decision subroutine shall be provided to determine, for an emitter exhibiting no ML, MA, or PAN conditions, whether display of the emitter is

required. The display decision shall be based on the criteria described in Section 5.2.1.1.

5.2.2.2 Emitter Insert Subroutine

An Emitter Insert Subroutine shall be provided to insert a trackfile entry into the Emitter Trackfile so as to maintain the priority order of the trackfile. This subroutine shall be used to insert new entries and to reinsert existing entries following a priority update.

5.2.2.3 Adaptive Ageout Subroutine

An Adaptive Ageout Subroutine shall be provided to perform Adaptive Ageout as described in Section 5.2.1.3 This shall be executed in the event that the CEPC parameter of an entry becomes zero during an update or is initialized to zero at the time of insertion of the entry. The PRI window used in the Adaptive Ageout Subroutine shall be a reprogrammable value stored in the EID table.

5.2.2.4 Normal Update

A Warnier-Orr chart of the normal update routine is provided in Figure 20.

5.2.2.5 Harmonic Update

The following data shall be updated in Harmonic Update:

PRI

Sine

Cosine

STOA

Power

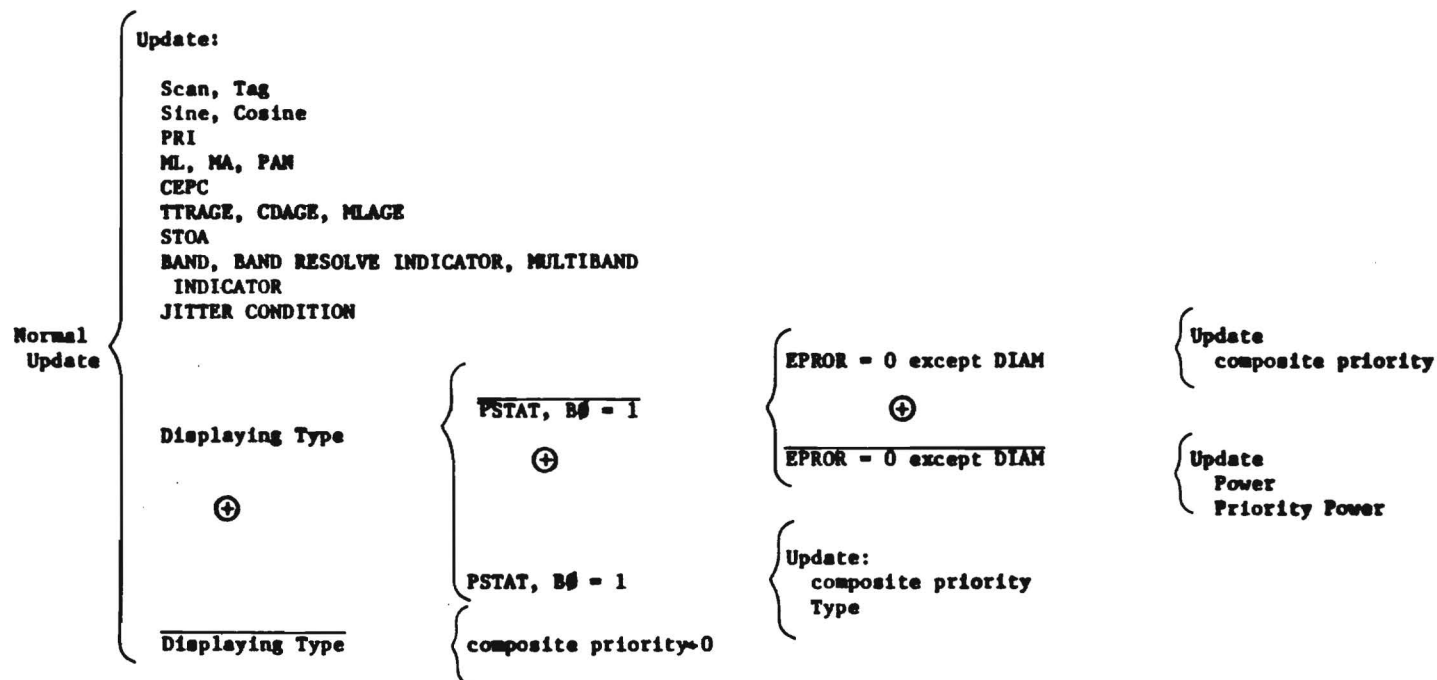


Figure 20. Warnier-Orr Chart of Normal Update Routine

Jitter condition

TYPE

Composite Priority

5.2.2.6 New Emitter Insertion

The New Emitter Insertion routine shall insert the following data:

PRI

Sine

Cosine

STOA

Power

Jitter Condition

TYPE

Composite Priority

CDAGE (initialized)

TTRAGE (initialized)

CEPC (initialized)

EX

EY

In the event that no room is available in the trackfile, the priority of the candidate emitter shall be compared to that of the lowest priority emitter in the trackfile. If the candidate's priority exceeds that of the trackfile emitter by an amount specified as a reprogrammable parameter in the EID file, the lowest priority emitter shall be deleted from the trackfile and the candidate inserted in priority order.

5.2.2.7 Stagger Detection

The Stagger Detection Routine shall increment the temporary stagger level in the trackfile entry of the matched emitter once for every match by the NØSS match routine in the snapshot after the first, except in the following cases:

1. The difference in STOA between the two pulsetrains is greater than the PRI.
2. The PRI is an integer multiple of the difference in STOA

The first case indicates that the second pulsetrain may be a fragment, as described in Section 3.3.1, rather than a valid Stagger Component.

The second case may arise due to an erroneous deinterleave by a sliding window search, as described in Section 3.3.2. (Such a deinterleave error may result, for instance, if an emitter switches to a lower PRI). In this case, the stagger level is left unchanged, and a flag (The Informed Pride Bypass bit) is set in the trackfile to indicate that the PRI in this entry is not to be used in a sliding window search in the next snapshot. This gives the binary search PRIDE routine an opportunity to retrieve the correct PRI.

APPENDIX

PRESERVED DATA STRUCTURES

A.1 TYPE Table

Rationale

The TYPE table contains characteristics of emitter types and, optionally, parameters to be used in attempting to match a tracked emitter of the given type.

Subdivisions

The Type Table is subdivided into a number of records, called TYPE sets, each corresponding to an emitter TYPE. Each TYPE Set contains eight words, most having several packed data elements.

Data Elements

EIDTO - pointer to alternate set if current table is invalid.

PRY (EIDT1, B4-B9) - index to the Priority Low/High Table which gives both a low altitude and a high altitude EID priority.

CEPC (EIDT2, B0-B2) - initial vlaue of Candidate Emitter Promotion Count.

BPADP (EIDT2, B4) = 1 if adaptive matching is not to be allowed for this emitter

AGEOT (EIDT2, B8-B11) - age limit for the EID parameters CDAGE and TTR AGE.

MLADP (EIDT3, B0-B3) - bits set if corresponding condition (ML, MA, DIA, and PAN respectively) is allowed for this emitter type.

SR (EIDT3, B5) = 1 if Scan Timer must be maintained by ETE.

UK (EIDT3, B7) = 1 if the TYPE set represents an unknown radar type.

MA = ML (EIDT3, B9) = 1 if missile launch and missile alert conditions are indistinguishable.

BAND (EIDT4, B0-B4) - frequency bands in which an emitter of the given type may occur.

SPECL (EIDT4, B5) = 1 if special PRI and angle windows are required.

PRIW (EIDT7, B0-B7) - special PRI window for Round 0 match loops

DELSC (EIDT7, B8-B11) - special angle window for match loops

A.2 Page 0 Control

Rationale

Page 0 Control Variables are locations in Page 0 RAM which contain information passed to ETE on call.

Subdivisions

Page 0 Control is not subdivided.

Data Elements

IFLG - IFLG, B15 is the informed PRIDE Flag. Set to indicate that the current P-emitter was deinterleaved with the assistance of Informed PRIDE.

TX, TY - Temporary X and Y passed in turn by ETE to XYCH, which calculates the initial EX, and EY parameters for a new record creation.

MODE - MODE, B12 specifies the current altitude of the plane as either high or low.

UKTGF - Unknown Toggle Flag; indicates whether an emitter having unknown type should be displayed.

IPFLG - Search Flag; indicates whether search radar-types should be displayed.

SRTC - Slow Real Time Clock.

DOETM - Keeps minimum time (according to SRTC) for next DOE pass.

MLDT - Keeps minimum time (according to SRTC) for next MLAGE test.

A.3 Temporary File

Rationale

The Temporary File includes all variables containing measured characteristics of an emitter.

Subdivisions

The Temporary File is not subdivided

Data Elements

PPRI - Measured pulse recurrence internal of the emitter.

PTYPE - Initial TYPE associated with the measured PRI of the emitter.

PSTOA - Starting time of arrival (TOA) - TOA of the first pulse in the pulsetrain.

PSIN - Raw sine of AOA

PCOS - Raw cosine of AOA.

PPROR - passes any ML, MA, or PAN conditions.

PPWR - Measured power of the emitter.

PBAND - Frequency band in which the emitter is intercepted.

JTFLG - Jitter flag set for a jittered intercept of the P-emitter

A.4 Emitter Trackfile

Rationale

Variables containing characteristics of previously intercepted emitters are stored in the Emitter Trackfile (ETF).

Subdivisions

ETF is subdivided into 16 records of 18 words each. Some words contain several packed data elements.

Data Elements

EFPTR - pointer to next emitter in file or to FEMIT if current entry is last in file

ETYPE - address of the emitter TYPE set.

EPRI - pulse recurrence interval of the emitter.

CD SIN (ESIN, B0-B7) - sine component of angle of arrival of last intercept in C/D band.

HIGH SIN (ESIN, B8-B15) - sine component of angle of arrival of last intercept in bands 1, 2 or 3.

CD COS (ECOS, B0-B7) - cosine component (as above).

HIGH COS (ECOS, B8-B15) - cosine component (as above).

ML (EPROR, B0) - missile launch flag.

MA (EPROR, B1) - missile alert flag.

DIA (EPROR, B2) - symbol to be displayed inside a diamond \diamond ; operator receives an audio signal.

PAN (EPROR, B3) - flag for panoramic reception.

M-BND (EPROR, B4) - set if the emitter occurs in two or more frequency bands.

PRIOR (EPROR, B5-B9) - fixed priority taken from TYPE set.

PRPWR (EPROR, B10-B15) - measured emitter power.

EBAND (EPWR, B0-B4) - frequency band(s) in which emitter has occurred.

MLAGE (EPWR, B5-B7) - time passed since last intercept with ML or MA status

JITP (EPWR, B8) - set if jitter possible

JITF (EPWR, B9) - set if jitter found

EPWR (EPWR, B10-B15) - emitter power.

CEPC (EAGE, B0-B2) - Candidate Emitter Promotion Count. Represents the number of times emitter must occur before it causes a display.

IPBP (EAGE, B3) - Informed Pride Bypass Bit.

SCAN LNT, TAG (EAGE, B4-B7) - timer for scan rate measurement cycle.

PKSTG (EAGE, B8-B10) - Peak Stagger Level

CDAGE (EAGE, B11-B15) - time passed since last intercept in band 0.

BR (EX, B0) - set if band resolution required

HF (EX, B1) - Harmonic Forgiveness Bit.

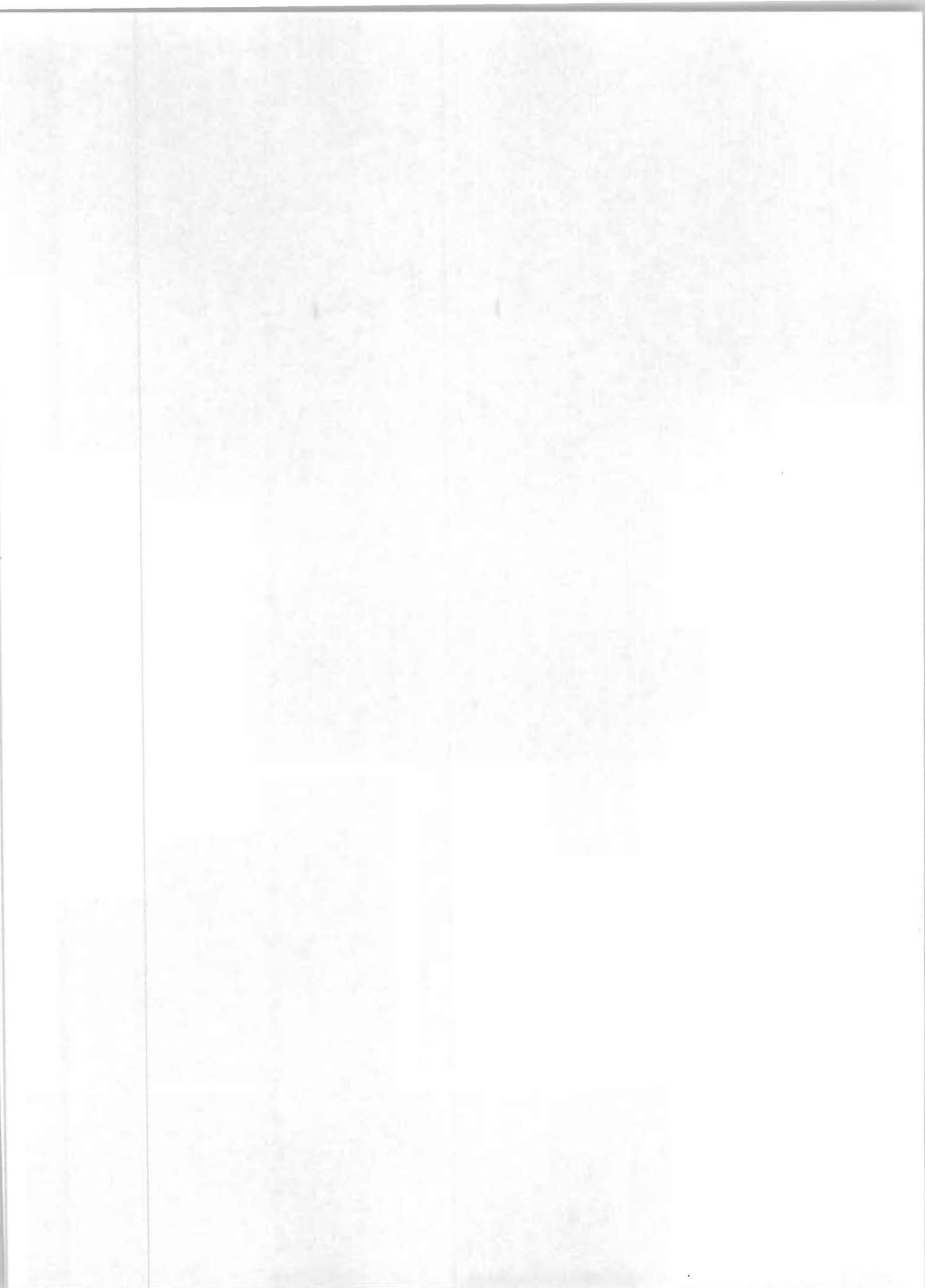
SF (EX, B2) - Stagger Forgiveness Bit.

ESTOA - start time of arrival of emitter in current snapshot.

TSTAG (EPWD, B0-B2) - temporary stagger level; non-zero only for current snapshot.

TTRAGE (EPWD, B3-B7) - time passed since last intercept in bands 1, 2 or 3.

AWPRI (EPWD, B10-B15) - PRI window for Round 1 match attempts.



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TEST PLAN
FOR A PERFORMANCE EVALUATION OF THE RESTRUCTURED ETE MODULE

By

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Beth Cockerham

CONTRACT F09603-78-G-4368-0004

Performed For

WARNER ROBINS AIR LOGISTICS CENTER
Robins Air Force Base
Warner Robins, Georgia

Foreword

This interim report documents a test plan for the performance evaluation of the restructured version of the Flight Program developed by the Engineering Experiment Station of the Georgia Institute of Technology. The project, ETE Restructuring, is under Contract #F09603-78-G-4368 Order #0004 for the United States Air Force, Warner Robins Air Logistics Center, Robins Air Force Base, Georgia 31098. The document was prepared in contractor format with DI-T-3203A used as a guide to content.

This project is conducted by the EW System Software Branch, Defense Systems Division (DSD) of the Systems Engineering Laboratory (SEL), Engineering Experiment Station, Georgia Institute of Technology. The project director for Georgia Tech is Mr. Andrew Lipscomb. The project is under the general supervision of Mr. Frank Vogler, branch head, Mr. Thomas M. Miller, division chief of DSD, and Mr. R. P. Zimmer, director of SEL.

1. Objectives

This document specifies a Test Plan for comparing the execution times of two versions of the Emitter Trackfile Entry (ETE) module of the ALR-46 Radar Warning Receiver V4 Operational Flight Program. The comparative testing is conducted as part of an effort to determine the feasibility of restructuring an existing Operational Flight Program (OFP) to produce a functionally equivalent program in a more easily maintained form. To this end, a restructured version of ETE has been produced using structured, modular design techniques. The current task is to determine changes in execution time resulting from the restructuring.

The comparative testing is complicated by the existence of discrepancies between the two versions. Although the initial aim of the project was to produce a functionally identical restructured version of ETE, a number of deficiencies were found in the original program, and required correction in the restructured version. Thus, prior to execution time testing, verification tests must be conducted to ensure that for each set of input test data both programs produce the same output.

2. Procedures

The test procedures presented in this section assume a working familiarity with the restructured ETE program. Readers lacking this background are referred to the ETE Functional Specification (CPCI Computer Program Development Specification prepared under this contract) for a detailed description.

2.1 Test Configuration

All comparative testing will be performed on the Data General ECLIPSE S-130 computer at Warner Robins Air Logistics Center. The ETE module will run in a test driver prepared by Georgia Tech. The test driver consists of a FORTRAN program which performs all I/O operations and an assembly language program which initializes the on-line data and contains a subroutine call to ETE. The assembly language program routine communicates with the FORTRAN program through a common block. In verification tests the driver runs ETE once, and prints the results. In execution time tests, the driver will be modified to reinitialize the input data and execute the routine again, con-

tinuing until a prespecified number of runs have been performed. Multiple runs per test are performed in execution time measurements to obtain better measurement resolution. When all runs are complete, the driver will print the execution time.

ETE will require input data as follows:

- . Data which are modified by ETE and must be initialized for each run:
 - Page Zero Control Data
 - Temporary File
 - Emitter Trackfile
- . Data which must be initialized for each test;
 - EID/OFD Data
- . Permanent Data
 - EID/TYPE Sets

The preceding considerations are presented in summary in a flowchart in Figure 1.

2.2 Test Cases

Approximately 30 test cases will be devised for the execution time testing. The test cases will be selected so as to provide execution time estimates for particular functions of the code, either directly or by comparison between tests. Selected test cases are described in the following subsections. This set of test cases may be modified or supplemented in consultation with the sponsor's technical representatives.

2.2.1 Match Routines

Tests 1 through 7 will test the execution time of the match routines. ETE will be executed with one entry in the trackfile. This entry will be matched as follows:

<u>Test Case</u>	<u>Match Routine</u>
1	NØSSMR
2	HØSSMR
3	N1SSMR
4	H1SSMR
5	N2JJMR
6	H2JJMR
7	UNSMR

The temp file and trackfile entries will be selected to minimize the time required for a rejection in each match routine preceding the one where the match occurs. In Test 2, HØSSMR will have the Harmonic Forgiveness option enabled, and the Stagger Forgiveness option disabled; this is the normal operating configuration. The trackfile entry data and match condition will be selected so that no update is performed.

2.2.2 Effect of Harmonic and Stagger Forgiveness Options

In Tests 8 and 9, Test 2 will be repeated, first with both options disabled, then with both options enabled. Effects of the options on execution time can be determined by comparisons among the three cases.

2.2.3 Insertion of New Entry

Tests 10 and 11 will determine the time required to insert a new entry into the trackfile, first with trackfile empty, then with one entry in the trackfile. The first test indicates the approximate time required by the insertion routine. The second test, by comparison with the first, indicates the time required for one entry to be rejected in all match loops.

2.2.4 Effect of Trackfile Loading

Tests 1 (NØSS match), 5 (N2JJ match), and 11 (new insertion) will be repeated with 5 and 10 entries in the trackfile to determine changes in execution time with trackfile loading. Test cases will be as follows:

<u>Test Case</u>	<u>Action</u>	<u>Number of Entries</u>
12	NØSS match	5
13	NØSS match	10
14	N2JJ match	5
15	N2JJ match	10
16	New insertion	5
17	New insertion	10

In each case the entries will be selected to provide a mixture of match rejection criteria.

2.2.5 Effect of UNSMLR

In Test 18, Test 17 will be repeated with the unstable emitter match loop (UNSMLR) disabled. Since an emitter must be rejected in all match loops before being entered into the trackfile, comparison of these tests will indicate the execution time of UNSMLR.

2.2.6 Update Routines

Tests 19 - 21 will determine execution time for the update routines as follows:

<u>Test Case</u>	<u>Match Routine</u>	<u>Update Routine</u>
19	NØSS	STGRDTR
20	NØSS	NUPDTSR
21	HØSS	HUPDTSR

Comparison of Tests 19 and 20 with Test 1 will provide execution time estimates for stagger detection and normal update. Comparison of Test 21 with Test 2 will provide an execution time estimate for harmonic update. In Test 20, the update will not require an adaptive ageout.

2.2.7 Effect of Adaptive Ageout

In Tests 22 and 23, Test 13 will be repeated. Test 22 will allow update without adaptive ageout. Test 23 will repeat Test 22 with adaptive ageout. Comparison of these tests will provide an estimate of the time required for adaptive ageout.

2.3 Verification Tests

Verification runs of the restructured ETE will be performed for each test case. The output will be inspected for correctness and recorded. The original version of ETE will then be run on each test case, and its output compared to that of the restructured ETE. In the event of a discrepancy, the original version of ETE will be modified to remove the discrepancy. The nature of the discrepancy and the required modification will be reported in the test results.

In order to ensure comparability between test cases, validation tests will be completed and modifications implemented for all cases before timing tests are begun.

2.4 Execution Time Tests

Execution time will be determined by first executing the test on the driver alone, with ETE replaced by a one line stub, then executing the test with ETE in place and taking the difference. Since the exact configuration of the driver may differ between cases and between the two versions,

as many as four measurements may be required in each case: two to determine driver execution time for the two versions and two to determine program execution time for the two versions.

Timing tests will be sufficiently accurate to detect a 1% difference in execution time between the two versions. The number of repetitions required to achieve this resolution will differ between cases and will be determined at the time of the test.

2.5 Test Results

Results of the Verification and Execution time tests will be reported for each test case. In addition, the cases will be compared and analyzed to determine changes in execution time of specific functions not tested explicitly. The results will be documented in the Final Engineering Report.

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CPCI COMPUTER PROGRAM PRODUCT SPECIFICATION
FOR THE
EMITTER TRACKFILE ENTRY MODULE
OF THE
ALR-46 OPERATIONAL FLIGHT PROGRAM

BY

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Beth Cockerham

Contract F09603-78-G-4368-0004

Performed for

Warner Robins Air Logistics Center
Robins Air Force Base
Warner Robins, Georgia 31098

FOREWORD

The CPCI Computer Product Specification provides detailed design documentation for the restructured Emitter Trackfile (ETE) Module of the ALR-46 Operational Flight Program. This document was prepared under Contract F09603-78-G-4368 Order No. 0004 for the United States Air Force, Warner Robins Air Logistics Center, Robins Air Force Base, Georgia 31098 with DI-E-30113 used as guide to content.

This project is conducted by the EW System Software Branch, Defense Systems Division (DSD) of the Systems Engineering Laboratory (SEL), Engineering Experiment Station, Georgia Institute of Technology. The project director for Georgia Tech is Mr. Andrew Lipscomb. The project is under the general supervision of Mr. Frank Vogler, branch head, Mr. Thomas M. Miller, division chief of DSD, and Mr. R. P. Zimmer, director of SEL.

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DESIGN SPECIFICATION

1.0 Introduction

This document contains the design specification for a restructured version of the Emitter Trackfile Entry (ETE) module of the ALR-46 Operational Flight Program, version V4. The motivation for this design was presented in the Functional Specification (CPCI Computer Program Development Specification). This document provides the detailed design information.

Restructured ETE will consist of 37 modules arranged hierarchically, as shown in Figures 1-1, 1-2, and 1-3. In the Figures, a module appears in a bracket if it may be called from the module associated with the bracket. Modules are referred to as either routines or subroutines. Functionally this distinction is of no significance; it refers only to the procedure used in accessing and returning from the module. Subroutines which are executed at more than one point in the program, are accessed using the "jump to subroutine" instruction of the assembly language, and require a Random Access Memory (RAM) location for storage of the return address. Routines, which are executed at only one point in the program, use direct jumps for access and return allowing more efficient use of RAM.

In each of the following sections, design documentation is presented for each module and for each data structure. The data structure documentation (in Section 2) describes the function and organization of the data, and defines each data location. The module documentation (in Section 3) consists of a text describing the function of the module, a list of routines called from the module, a list of data locations accessed or changed in the module (data locations are grouped by data structure), and a Warnier-Orr chart of the module. Each routine listed under "Routines Called" will be described in depth under its own heading.

2.0 ETE Data Structures

The data accessed by ETE can be divided into two sections according to

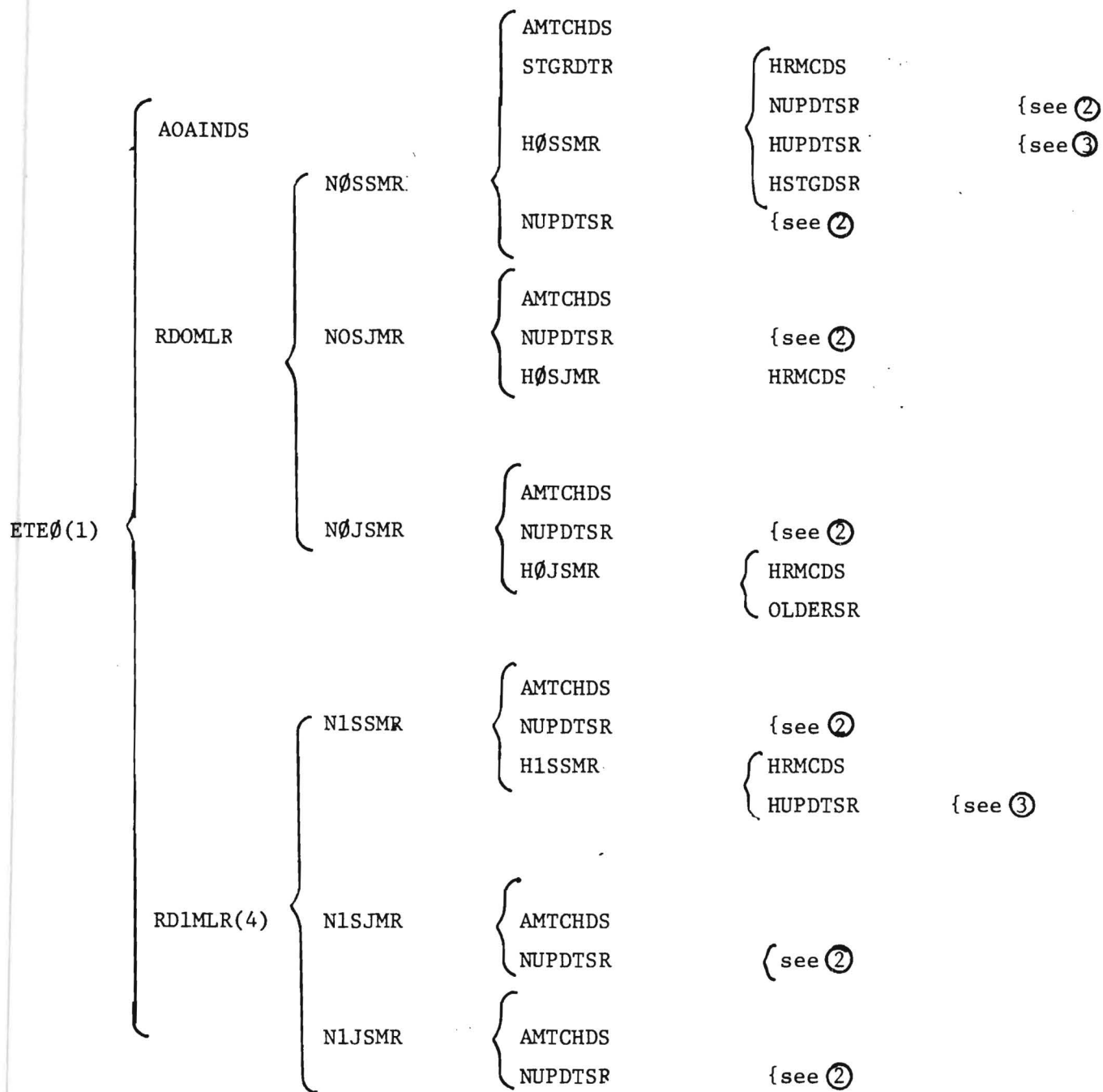
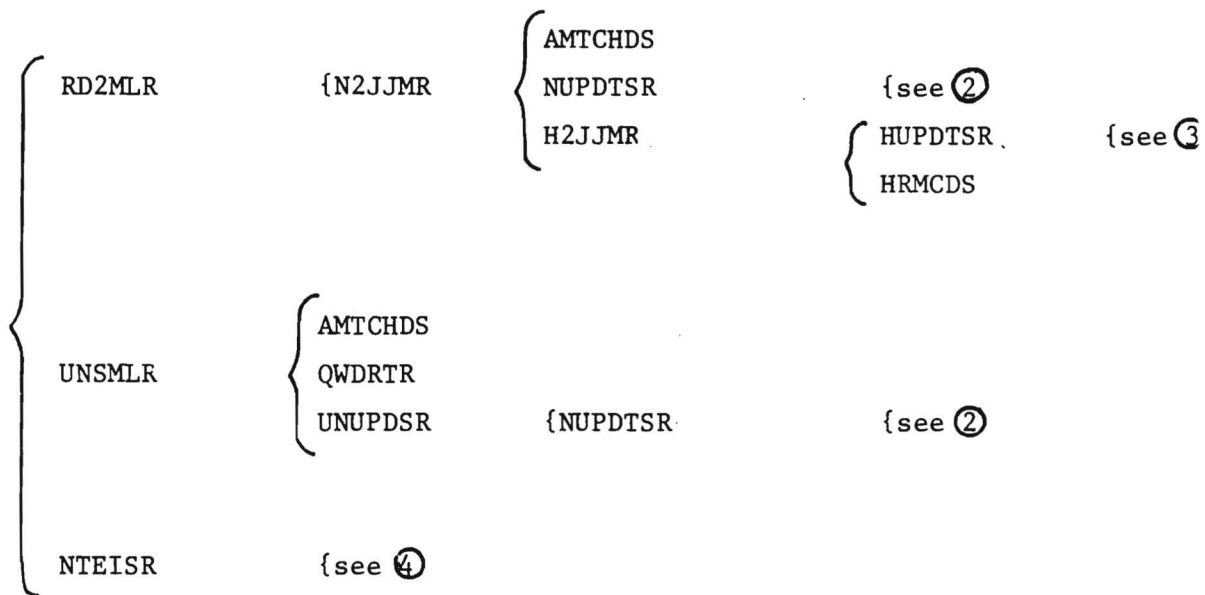


Figure 1-1.

ETEØ
(Continued)



NUPDTSR

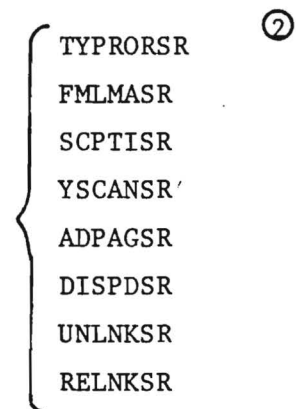


Figure 1-2.

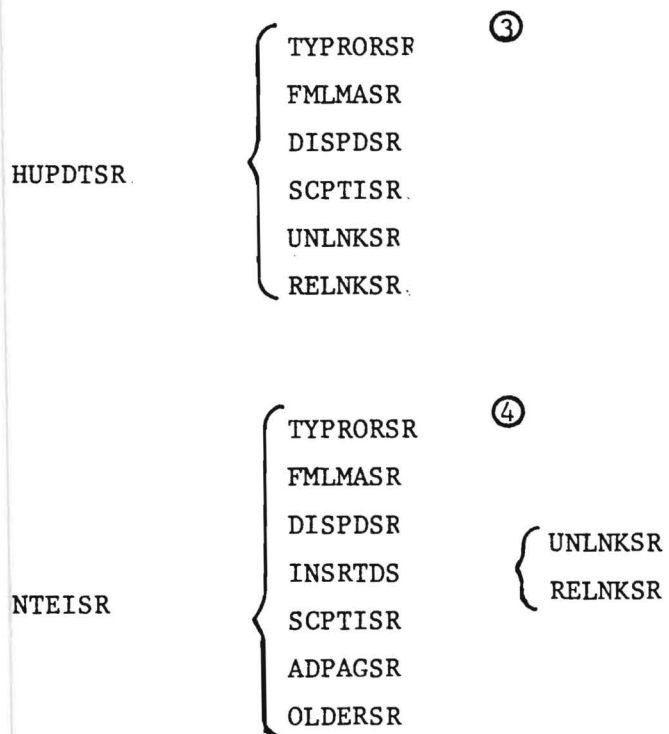


Figure 1-3.

physical storage considerations. Data which is modifiable on line is stored in Random Access Memory (RAM), and fixed data stored in Programmable Read Only Memory (PROM).

2.1 RAM Locations

The RAM portion of available memory consists of Page 0 (the first 128 words of the processor memory) and the Emitter Trackfile.

Although no formal organizational structure exists for Page 0, it may be functionally divided as follows: 1) Temporary File, 2) Page 0 Control, 3) ETE Internal and 4) Scratchpad. The first three subsections are each briefly described below and followed by a list of defined data elements. Scratchpad is a set of temporary storage locations for data not passed between modules. The various uses for Scratchpad are given under the heading "Internal Data" in the module documentation.

Temporary File

The Temporary File contains measured characteristics of the intercept currently processing.

PPRI	Pulse repetition interval
PTYPE	Pointer to associated TYPE set record
PSTOA	Start time of arrival
PSIN	Measured sine component of angle of arrival
PCOS	Measured cosine component of angle of arrival
PPROR	Contains flags for missile launch, missile alert, diamond selection, and panoramic reception
PPWR	Measured emitter power
PBAND	Frequency band of intercept
JTFLG	Contains flag for jittered intercept

Page 0 Control

Page 0 Control contains variables which control OFP execution and are shared by ETE and other OFP modules.

IFLG	Informed PRIDE Flag; intercept was deinterleaved with Informed PRIDE
TX	Temporary x-display coordinate
TY	Temporary y-display coordinate
MODE	Contains altitude high/low switch
UKTGF	Unknown Toggle Flag
IPFLG	Flag for the condition that search radars must be displayed
SCFLG	Storage location for band parameter used by scan rate measurement routine

ETE Internal

ETE Internal contains variables accessed only by ETE modules.

PRIW	PRI match window
DELSC	Angle match window
MATCH	Flag for the condition that a match has occurred
INKR	Harmonic match window increment
PAFLG	P-emitter age flag
LPRI	Larger of EPRI and PPRI; passed to Harmonic Match Decision Routine
SPRI	Smaller of EPRI and PPRI; passed to Harmonic Match Decision Routine
FPROR	Type-dependent fixed priority

Emitter Trackfile

The Emitter Trackfile occupies 16 contiguous data blocks in RAM on which

emitter records are written. The emitter record consists of 12 words (many with packed data elements) which are relevant to ETE. Operationally, the Trackfile is a linked list ordered by emitter priority. A pointer to the first record in the list appear in Page 0. The data elements accessed by ETE are defined below.

EFPTR	Contains address of next active record of lower priority unless the current record is lowest in priority, in which case EFPTR contains the page 0 address, FEMIT
ETYPE	Contains the EID table address of the TYPE set associated with the entry
EPRI	Contains the pulse recurrence interval associated with the entry
HBSIN(ESIN, B8-B15)	Contains sine component of AOA of last high band intercept
HBCOS(ECOS, B8-B15)	Contains cosine component of AOA of last high band intercept
ML(EPROR, B0)	Missile Launch indicator
MA(EPROR, B1)	Missile Alert indicator
DIAM(EPROR, B2)	Set if symbol associated with entry must be enclosed in a diamond for display
PAN(EPROR, B3)	Panoramic reception flag
MLTBND(EPROR, B4)	Set if entry has occurred in two or more frequency bands
TYPRR(EPROR, B5-B9)	TYPE-dependent fixed priority value
PROPWR(EPROR, B10-B15)	Measured emitter power
EBAND(EPWR, B0-B4)	Contains indicators for bands in which entry has occurred
MLAGE(EPWR, B5-B7)	Time passed since last intercept with missile launch or alert status
JTP(EPWR, B9)	Set if a jittered intercept has been received
EPWR(EPWR, B10-B15)	Measured emitter power

CEPC(EAGE, B0-B2)	Candidate Emitter Promotion Count
IPBP(EAGE, B3)	Informed Pride Bypass bit
SCANTMR(EAGE, B4-B7)	Timer for scan rate measurement routine
PKSTG(EAGE, B8-B10)	Peak Stagger Level
CDAGE(EAGE, B11-B15)	Time passed since last band of intercept
BDRSRQ(EX, B0)	Set if the band resolution routine should be performed
HFGNBT(EX, B1)	Harmonic Forgiveness bit
STFGNBT(EX, B2)	Stagger Forgiveness bit
XSGN(EX, B5)	Sign of x-coordinate of display symbol
ABSX(EX, B5)	Absolute value of x-coordinate
YSGN(EY, B5)	Sign of y-coordinate
ABSY(EY, B6-B15)	Absolute value of y-coordinate
ESTOA	Contains start time of arrival if entry has occurred in most recent snapshot
TSTAG(EPWD, B0-B2)	Counter for stagger level
TTRAGE(EPWD, B3-B7)	Time passed since last intercept in bands 1, 2, or 3
AWPRI(EPWD, B10-B15)	Adaptive PRI Window; used in Round 1

2.2 PROM Locations

The PROM Locations, normally referred to collectively as the Emitter Identification (EID) file contain a fixed data base. Portions relevant to ETE include the Emitter TYPE table and the Operational Flight Program (OFP) data.

TYPE Table

The TYPE table consists of records, called TYPE sets, containing emitter specific threat parameters and OFP control variables. Each record consists of

seven words (most with packed data elements). A tracked emitter is linked to a TYPE record via a TYPE variable (actually a pointer to the TYPE set record). The data elements accessed by ETE are given below.

PRY(EIDT1, B4-B7)	Index to the High Low Table, which contains fixed priority values
CEPC(EIDT2, B0-B2)	Initial CEPC value
BPADP(EIDT2, B4)	Bypass Adaptive Match bit
AGEOT(EIDT2, B8-B11)	Maximum emitter age
TMLADP(EIDT3, B0-B3)	Contains flags for allowable conditions among ML, MA, DIA and PAN (see "Emitter Trackfile" description)
SR(EIDT3, B5)	Scan Required flag
UK(EIDT3, B7)	Flag for unknown emitter TYPE
MAEML(EIDT3, B9)	Flag for the condition that missile launch and missile alert are indistinguishable
TBAND(EIDT4, B0-B4)	Contains flags for bands in which emitter TYPE intercepts may occur
TSPECIAL(EIDT4, B5)	Flag for Special TYPE
PRIW(EIDT7, B0-B7)	PRI window for Special TYPE
DELSC(EIDT7, B8-B11)	Angle window for Special TYPE
SPWPTR(EIDT7, B12-B15)	Pointer to Special Window table

OFP Data

OFP Data includes all parameters of the OFP which are not emitter specific. OFP Data is divided into a number of subsets, most of which are accessed by one module or a small set of modules which are parallel in function. The functions of the various subsets are highly routine-dependent and will be described as part of the individual module documentation.

3.0 Module Documentation

Conceptually, ETE can be divided into a match section and an update section.

The match section attempts to match measured characteristics of an emitter to emitter characteristics already recorded in the trackfile. The update section updates the matched entry or creates a new entry if no match is achieved. Although this distinction is valid, it is not reflected in the control hierarchy; the complexity of the matching procedure necessitates a design in which the update routines are interspersed within a hierarchy defined by the matching logic. Nonetheless, the match-update distinction is a valuable aid to understanding ETE. Thus the module documentation is divided into two subsections. Section 3.1 describes modules associated with matching, and Section 3.2 describes modules associated with updating.

3.1 Match Section

Subroutine ETEO

Function :

ETEO is the top level driver of the ETE module. Following Angle of Arrival verification, ETEO calls the match routines in sequence until a match is achieved or all match routines have failed. If no match is achieved, the New Trackfile Entry Insert Subroutine is called.

Routines Called :

ADAINDS - Angle of Arrival Initialization Decision Subroutine.
RDOMLR - Round Zero Match Loop Routine.
RD1MLR - Round One Match Loop Routine.
RD2MLR - Round Two Match Loop Routine.
UNSMR - Unstable Emitter Match Routine.
NTEISR - New Trackfile Entry Insert Subroutine.

Locations Accessed :

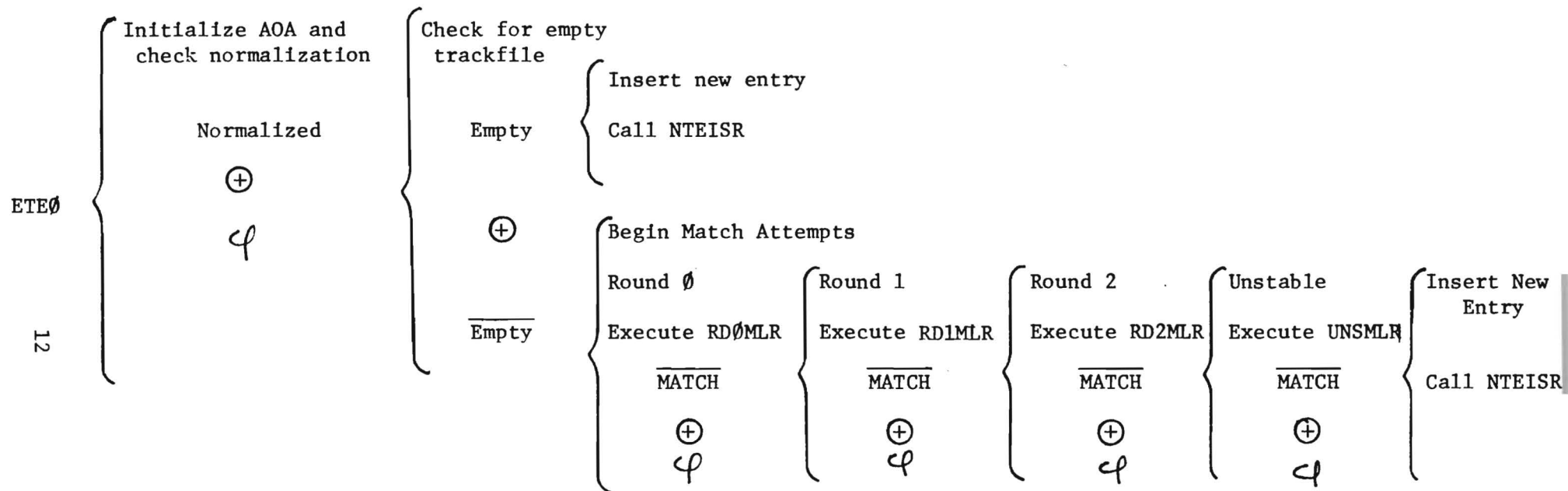
PO Control : AFEMIT
 FEMIT
Temp File : JTFLG
ETE Internal : MATCH

Locations Changed :

ETE Internal : PAFLG (Initialized)
 MATCH (Initialized)

Internal Data :

RTN1 - Saves return address.



Subroutine ADAINDS - Angle of Arrival Initialization Decision Subroutine.

Function :

ADAINDS performs all initialization of ADA (PSIN, PCOS) data. This includes, in Bands 1, 2, and 3 :

1. Storage of raw sine and cosine values in SCSIN and SCCOS (if indicated by SCFLG).
2. Normalization of sine and cosine values, if possible.

And, in Band 0 where no ADA data is available, setting PSIN and PCOS to zero.

SCFLG is set to indicate that a scan measurement is in progress at the angle specified by SCSIN and SCCOS and, thus, the current values are not to be changed.

Sine and cosine cannot be normalized if both values differ from the midpoint of the scale (174 octal) by less than the value SMIN1, and the sum of the differences is less than SMIN2. Otherwise the raw sine and cosine values are replaced by normalized values taken from the table SCTBL.

If sine and cosine are normalized, ADAINDS skips the instruction following the call.

Routines Called :

None.

Locations Accessed :

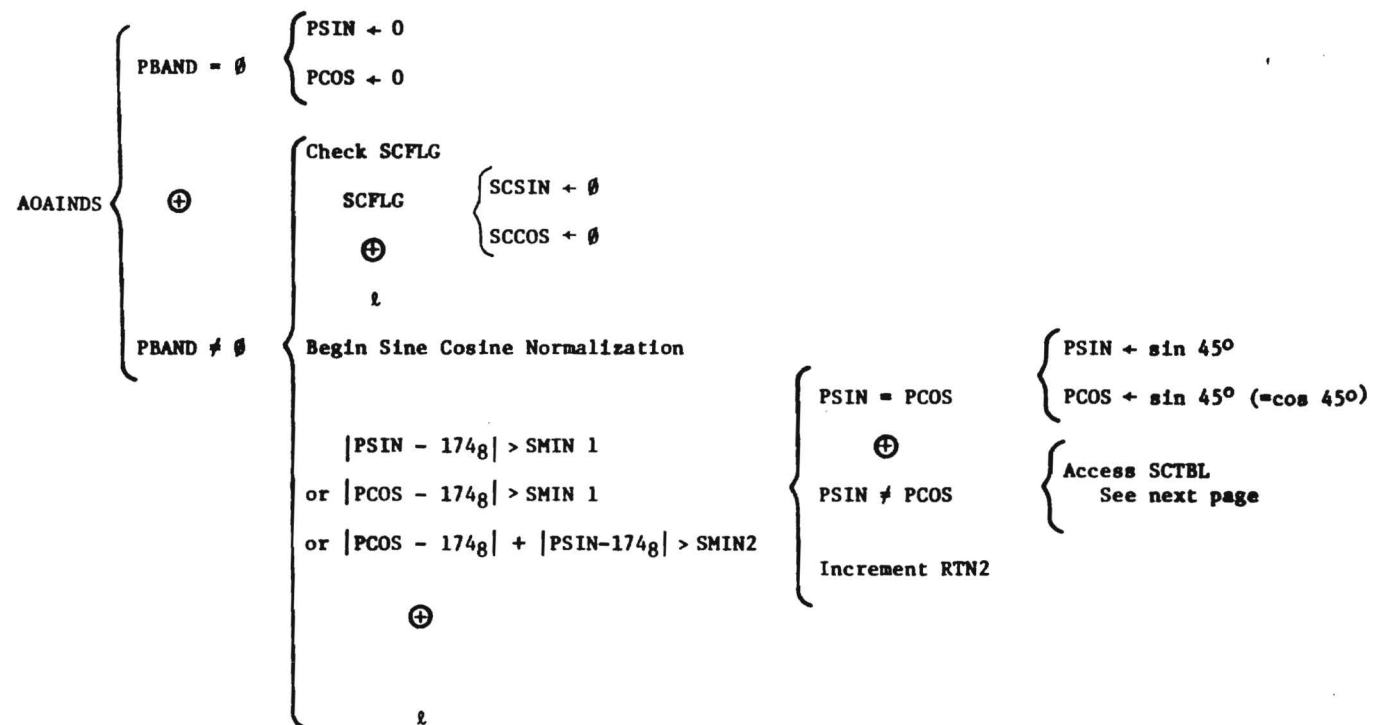
PO Control : SCFLG
Temp File : PBAND
 PSIN
 PCOS
OFF Data : SCMIN1
 SCMIN2

Locations Changed :

PO Control : SCSIN
 SCCOS
Temp File : PSIN
 PCOS

Internal Data :

RTN2 - Saves return address.
TMPSN - Stores temporary value of sin.
TMPCS - Stores temporary value of cos.



SCTB2
Access
Procedure

Compute 5 bit ratio

$$n = \frac{\text{Min } \{ |PSIN - 174_8|, |PCOS - 174_8| \}}{\text{Max } \{ |PSIN - 174_8|, |PCOS - 174_8| \}}$$

Use n to index table &
retrieve SCTBL word

PSIN < PCOS

⊕

PSIN > PCOS

PSIN ← Max {left byte, 370g - left byte}

PCOS ← Max {right byte, 370g - right byte}

PSIN ← Max {right byte, 370g - right byte}

PCOS ← Max {left byte, 370g - left byte}

Routine RDOMLR - Round Zero Match Loop

Function :

For each entry in the trackfile, RDOMLR calls the appropriate match routine based on the stable-jitter combination of the emitters. Match attempts continue until a match is successful or all emitters in the trackfile have been tested.

Routines called :

NOSSMR - Round 0, P-stable, E-stable Match Routine.
NOSJMR - Round 0, P-stable, E-jittered Match Routine.
NOJSMR - Round 0, P-jittered, E-stable Match Routine.

Locations Accessed :

PO Control : FEMIT
 AFEMIT
ETF : JTF (EPWR, B9)
Temp File : JTFLG
ETE Internal : MATCH

Locations Changed :

None.

Internal Data :

None.

RDØMLR

{ Trackfile Entry
(1, E)

{	P Stable	{	E Stable	{	NØSSMR
	⊕	{	⊕	{	NØSJMR
			E Jittered		
{	⊕	{	E Stable	{	NØJSMR
			⊕		
	P Jittered	{	⊕		
			⊕		

Routine NOSSMR

Function :

NOSSMR is the normal, round zero, P-stable, E-stable match routine.

Routines Called :

AMTCHDS - Angle Match Decision Subroutine.
HOSSMR - Harmonic, Round Zero, P-stable, E-stable Match Routine.
NUPDTSR - Normal Update Subroutine.
STORDTR - Stagger Detection Routine.

Locations Accessed :

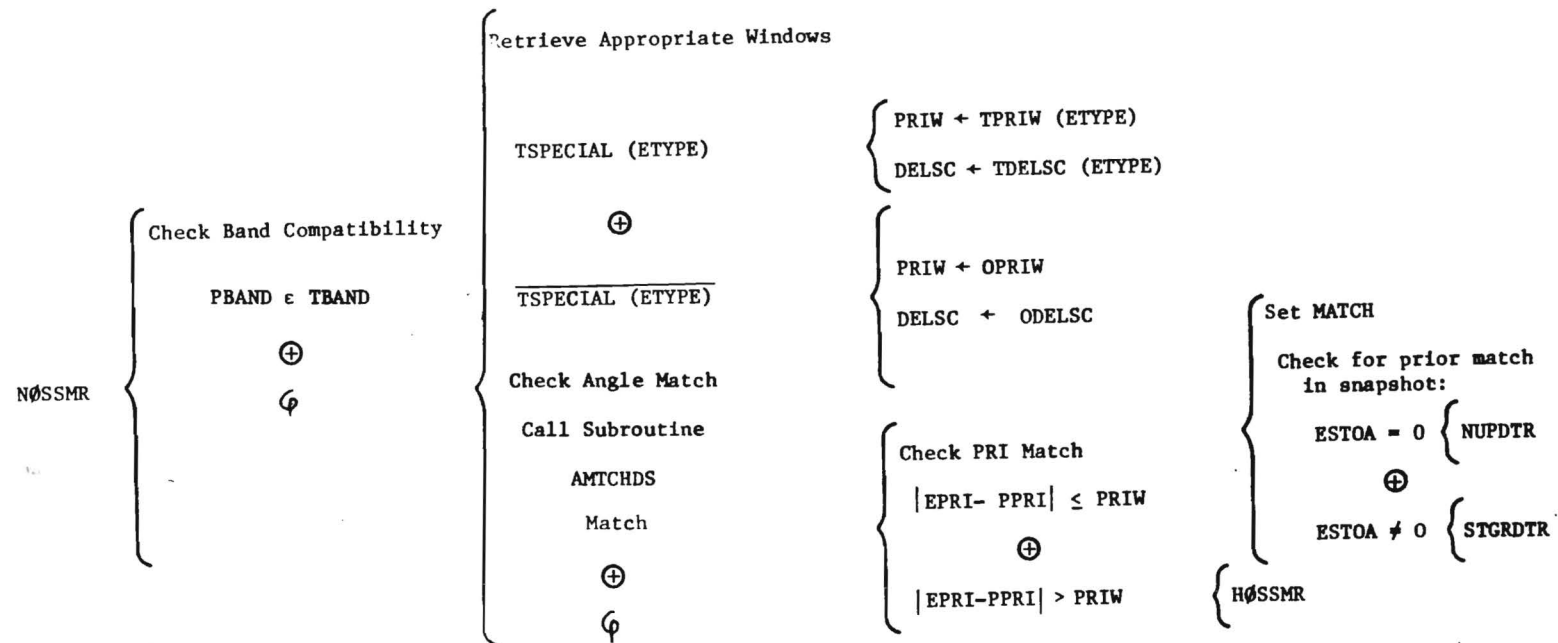
Temp File : PBAND
 PPRI
ETF : ETYPE
 EPRI
 ESTOA
ETYPE Set : TBAND (EIDT4, B0-B4)
 TSPECIAL (EIDT4, B5)
 TPRIW (EIDT7, B0-B7)
 TDELSC (EIDT7, B8-B11)
OFP Data : OPRIW
 ODELSC

Locations Changed :

ETE Internal : PRIW
 DELSC
 MATCH

Internal Data :

None.



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Routine STGRDTR

Function :

STGRDTR detects deinterleaved components of a staggered pulsetrain, and updates the temporary stagger level and CEPC of the entry if required. The second match to an entry within a snapshot is considered a valid stagger component unless :

1. $ABS (ESTOA - PSTOA) \geq PPRI$, indicating that the P-data may have originated from a fragment of the pulsetrain which was not deinterleaved in the first pass by PRIDE

or

2. $PPRI$ is an integer multiple of $ABS (ESTOA - PSTOA)$ (within 300 nsec) and the pulsetrain was deinterleaved by Informed PRIDE (the latter indicated by IFLG in the PO control data), indicating a possible erroneous deinterleave of an unstaggered pulsetrain into components.

The latter case may result, for instance, when a tracking radar changes PRI between snapshots. A flag, IPBP, is set in this case, indicating that EPRI should not be used in an Informed PRIDE search in the next round of deinterleaving. This will allow Binary PRIDE to retrieve the correct PRI.

CEPC is decremented for each level of stagger encountered unless it is already 1. In this case CEPC is not decremented. This ensures that the entry must be matched by data originating in at least 2 distinct snapshots before CEPC reaches zero.

Routines Called :

None.

Locations Accessed :

Temp File : PSTOA
 PPRI
PO Control : IFLG
ETF : ESTOA

Locations Changed :

ETF : IPBP (EAGE, B3)
 TSTAQ (EPWD, B0-B2)
 CEPC (EAGE, B0-B2)

Internal Data :

None.

$$\begin{array}{l}
 \text{STGRDTR} \left\{ \begin{array}{l} |PSTOA-ESTOA| < PPRI \\ \oplus \\ \phi \end{array} \right. \left\{ \begin{array}{l} \overline{IFLG \wedge n*} |PSTOA-ESTOA| = PPRI \\ \oplus \\ IFLG \wedge n* |PSTOA-ESTOA| = PPRI \end{array} \right. \left\{ \begin{array}{l} TSTAG < 7 \\ \oplus \\ \phi \\ IPBP \leftarrow 1 \end{array} \right. \left\{ \begin{array}{l} TSTAG \leftarrow TSTAG + 1 \\ CEPC \leftarrow \text{Max}(CEPC-1, 1) \end{array} \right.
 \end{array}$$

Routine NOSJMR

Function :

NOSJMR is the normal, round zero, P-stable, E-jittered match routine.

Routines Called :

AMTCHDS - Angle Match Decision Subroutine.
HOSJMR - Harmonic, Round Zero, P-stable, E-jittered Match Routine.
NUPDTSR - Normal Update Subroutine.

Locations Accessed :

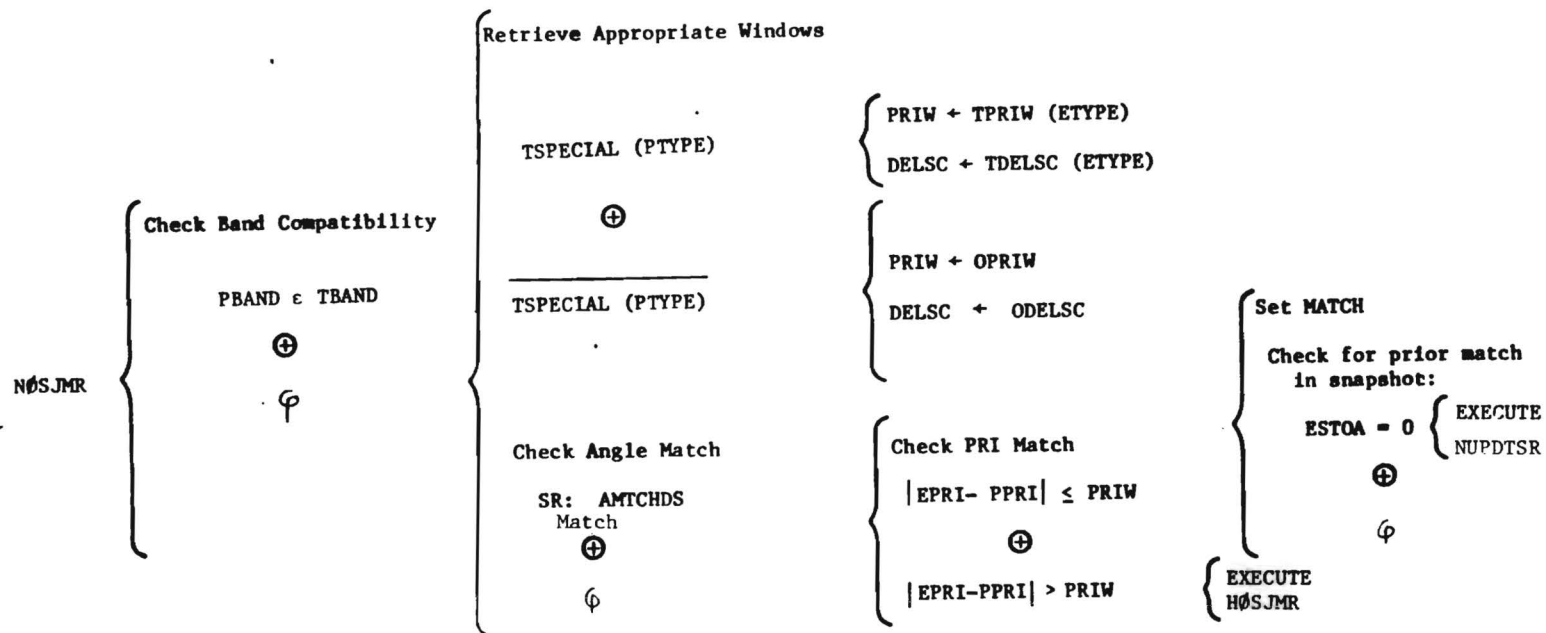
Temp File : PBAND
 PPRI
 PTYPE
ETF : EPRI
 ESTOA
ETYPE Set : TBAND (EIDT4, B0-B4)
 TSPECIAL (EIDT4, B5)
 TPRIW (EIDT7, B0-B7)
 TDELSC (EIDT7, B8-B11)
QFP Data : OPRIW
 ODELSC

Locations Changed :

ETE Internal : PRIW
 DELSC
 MATCH

Internal Data :

None.



Routine NOJSMR

Function :

NOJSMR is the normal, round zero, P-jittered, E-stable match routine.

Routines Called :

AMTCHDS - Angle Match Decision Subroutine.
HOJSMR - Harmonic, Round Zero, P-jittered, E-stable Match Routine.
NUPDTSR - Normal Update Subroutine.

Locations Accessed :

Temp File : PBAND
 PPRI
ETF : ETYPE
 EPRI
ETYPE Set : TBAND (EIDT4, B0-B4)
 TSPECIAL (EIDT4, B5)
 TPRIW (EIDT7, B0-B7)
 TDELSC (EIDT7, B8-B11)

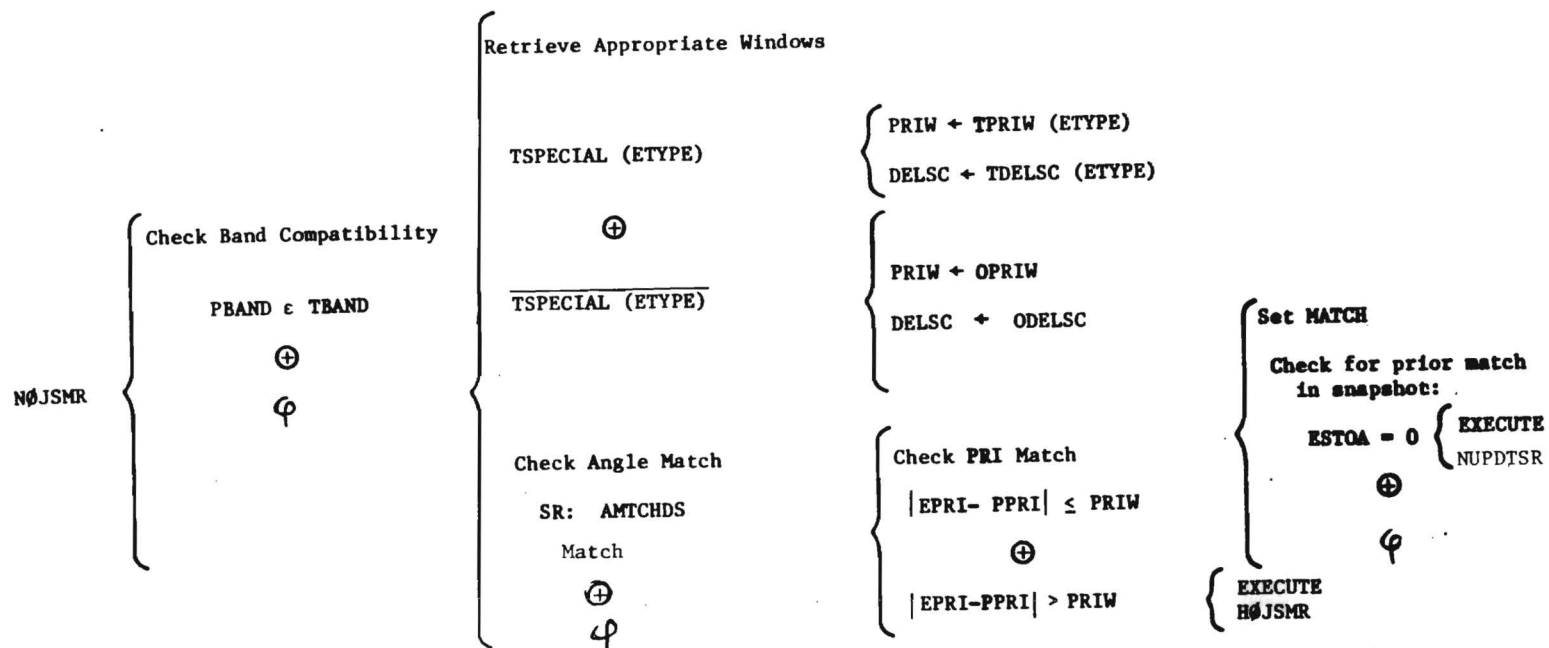
OFP Data : OPRIW
 ODELSC

Locations Changed :

ETE Internal : PRIW
 DELSC
 MATCH

Internal Data :

None.



Routine HOSSMR

Function :

HOSSMR is the harmonic, round zero, P-stable, E-stable match routine. Harmonic Forgiveness and Stagger Forgiveness variations are available in HOSSMR. These may be enabled or disabled through the OFP data. HOSSMR uses the same PRI window as NOSSMR and an increment equal to the PRI window.

Routines Called :

HRMCDS - Harmonic Match Decision Subroutine.
NUFDTSR - Normal Update Subroutine.
HUPDTSR - Harmonic Update Subroutine.

Locations Accessed :

ETF : EDAND (EPWR, B0-B4)
EPRI
ESTOA
Temp File : PBAND
OFP : HASWCH - indicates the status of Harmonic
Forgiveness and Stagger Forgiveness
HSTBL (Stagger Table)

Locations Changed :

ETE Internal : MATCH
INKR
LPRI
SPRI
ETF : STFGNBT
HFGNBT
TSTAG

Internal Data :

None.

HØSSMR

27

EPRI > PPRI
 \oplus
PPRI > EPRI

INKR \leftarrow PRIW
Call HRMCDS
Match
 \oplus
 ϕ

Set MATCH
2nd Harmonic
 \oplus

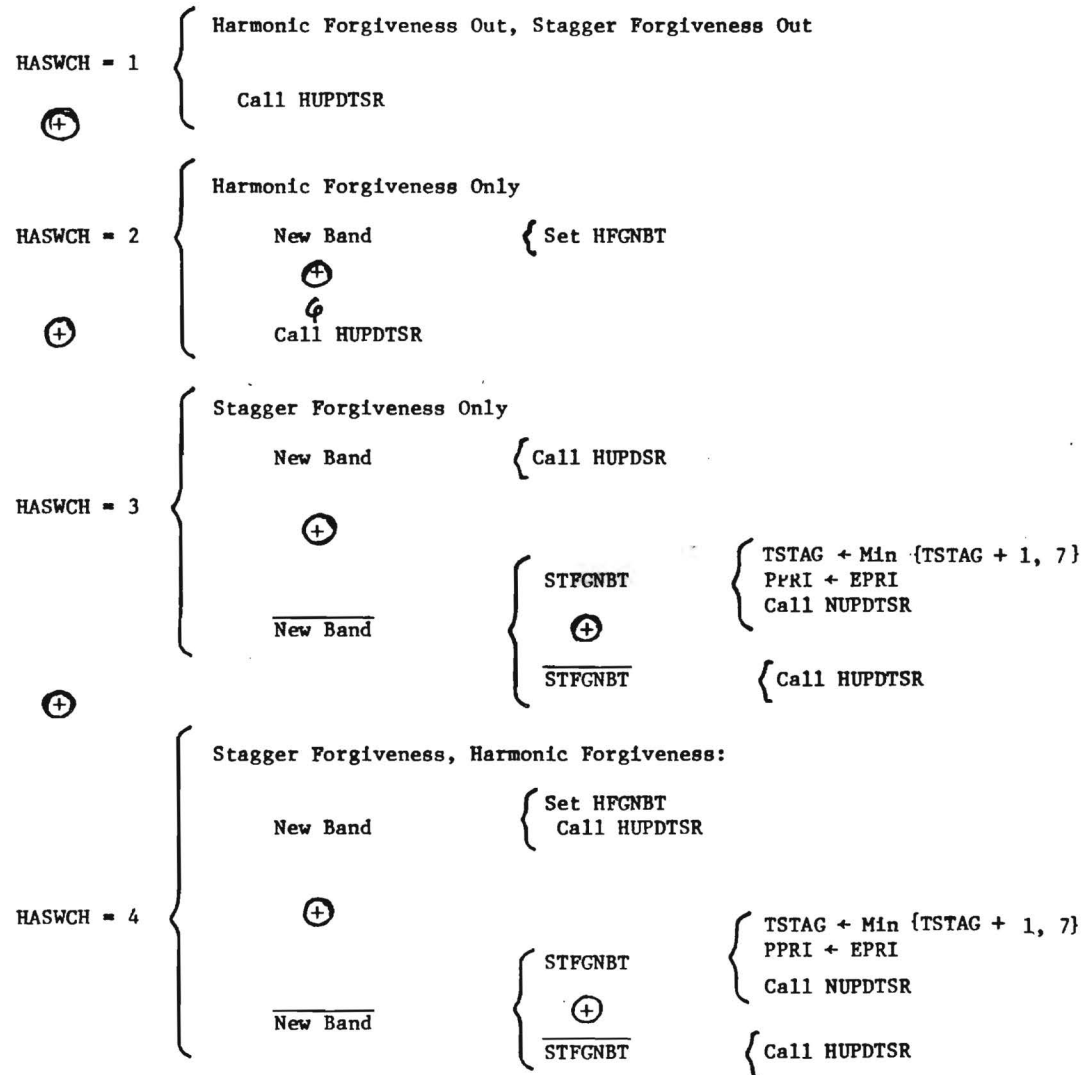
2nd Harmonic
{ See 9
{ Call HUPDTSR

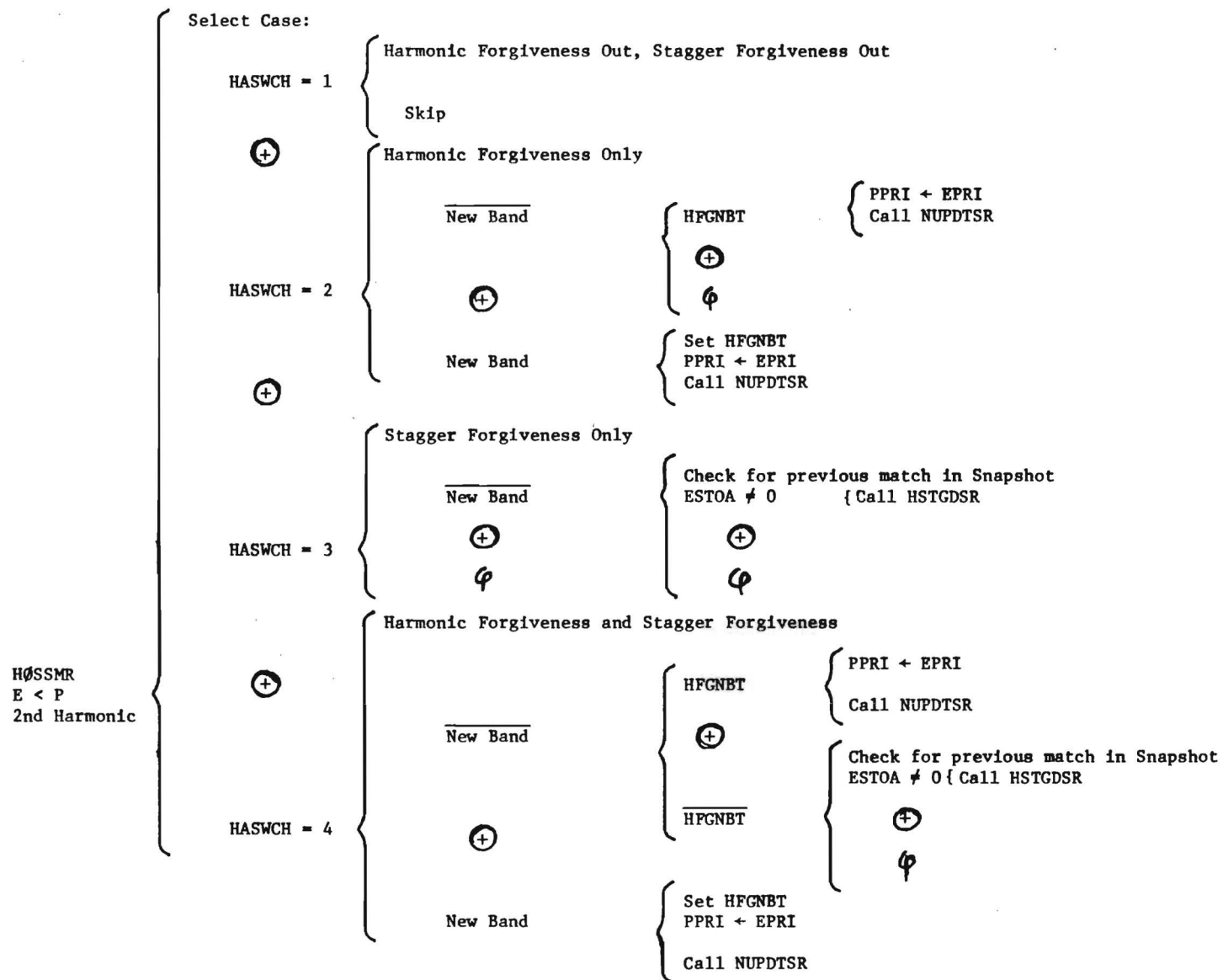
INKR \leftarrow PRIW
Call HRMCDS
Match
 \oplus
 ϕ

Set MATCH
2nd Harmonic
 \oplus
 ϕ
{ See 10

H0SSMR
2nd HRM
E > P

Select Case:





Subroutine MSTQDSR

Function :

MSTQDSR detects harmonic stagger, a condition in which the component PRI's of a staggered emitter are harmonically related. The P-emitter has been determined to match a tracked emitter on entrance. MSTQDSR searches the Stagger Forgiveness table for PTYPE and, if found, corrects the temporary stagger level and sets the Stagger Forgiveness bit.

Routines Called :

None

Locations Accessed :

OFF Data : Stagger Forgiveness table (TB46T)

Type set : PTYPE
 PSTOA
ETF : ESTOA
 EPRI

Locations Changed :

ETF : STFONBT (EX,B2) - Harmonic Forgiveness bit
 TSTAG (EPWD,B0-B2) - Temporary stagger level

Internal Data

RTN2 - Saves return address

HSTGDSR

Search HSTBL for PTYPE

HSTBL Entry
(1, E)

PTYPE = Entry

⊕

φ

If PTYPE in HSTBL,
Check for Harmonic Stagger:

| ESTOA - PSTOA | = $\frac{EPRI}{2}$

⊕

φ

Set STFGNBT
TSTAG + 2
Call HUPDTSR

Routine HOSJMR

Function :

HOSJMR is the harmonic, round zero, P-stable, E-jittered match routine. Harmonic matches involving a stable-jitter combination are, in most cases, invalid; thus HOSJMR does not lead to a trackfile update. A possible valid match may occur if $PPRI > EPRI$, however. For most match routines this match would lead to no action - neither update nor insertion of a new record. Since the match here may or may not be valid, a compromise position is adopted. PAFLG is set indicating that, if the P-emitter fails all succeeding matches and is inserted as a new emitter, its age parameters will be inserted at half their ageout value. Thus if the entry is not updated quickly in a future match, it will be removed from the trackfile.

HOSJMR uses a dedicated match window stored in the OFP data, and sets the increment equal to the window.

Routines Called :

HRMCDS - Harmonic Match Decision Subroutine.

Locations Accessed :

Temp File : PPRI
ETF : EPRI
OFP : OHPRIW - dedicated match window

Locations Changed :

ETE Internal : PAFLG
PRIW
INKR
LPRI
SPRI

Internal Data :

None.

HØSJMR

PPRI > EPRI

⊕

φ

PRIW ← OHPRIW

INKR ← OHPRIW

Call HRMCD

Harmonic match

⊕

φ

Increment PAFLG

Routine HOJSMR

Function :

HOJSMR is the harmonic, round zero, P-jittered, E-stable match routine. No match is allowed unless the stable emitter (here the E-emitter) has the greater PRI; in addition, the E-emitter must not be staggered. If the match succeeds, the stable emitter is made to appear older but remains in the trackfile and is not otherwise updated. The routine returns to the match loop after substituting PRI and TYPE in the Temp File.

HOJSMR uses a basic PRI window of EPRI/16 and a zero increment.

Routines Called :

HRMCDS - Harmonic Match Decision Subroutine.
OLDERSR - Subroutine to increase age parameter of ETF entry.

Locations Accessed :

ETF : EPRI
PKSTG (EAGE, BB-B10)
ETYPE
Temp File : PPRI

Locations Changed :

ETE Internal : PRIW
INKR
Temp File : PPRI
PTYPE

Internal Data :

None.

HØJSMR

$$\left\{ \begin{array}{l} \text{PPRI} < \text{EPRI} \end{array} \right.$$

⊕

φ

$$\left\{ \begin{array}{l} \text{PRIW} \leftarrow \text{EPRI}/16 \end{array} \right.$$

$$\text{INKR} \leftarrow \emptyset$$

Call HRMCDS

Match

⊕

φ

$$\left\{ \begin{array}{l} \text{Check for E-Stagger} \end{array} \right.$$

$$\text{PKSTG} = \emptyset$$

⊕

φ

$$\left\{ \begin{array}{l} \text{Call OLDERSR} \end{array} \right.$$

$$\text{PTYPE} \leftarrow \text{ETYPE}$$

$$\text{PPRI} \leftarrow \text{EPRI}$$

Routine RD1MLR - Round One Match Loop

Function :

For each entry in the trackfile, RD1MLR calls the appropriate match routine based on the stable-jitter combination of the emitters. Match attempts continue until a match is successful or all emitters in the trackfile have been tested.

Routines called :

NISSMR - Round 1, P-stable, E-stable Match Routine.
NISJMR - Round 1, P-stable, E-jittered Match Routine.
NIJSBR - Round 1, P-jittered, E-stable Match Routine.

Locations Accessed :

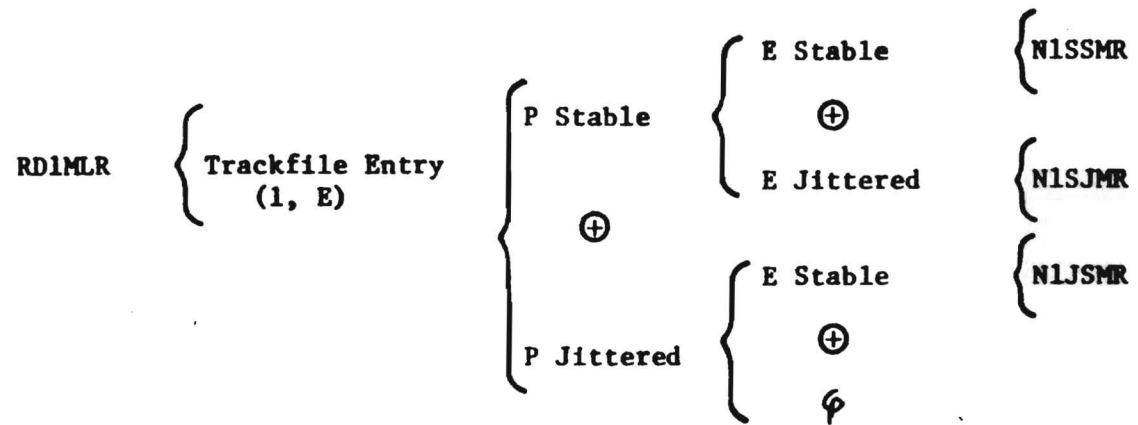
PO Control : FEMIT
 AFEMIT
ETF : JTF (EPWR, B9)
Temp File : JTFLG
ETE Internal : MATCH

Locations Changed :

None.

Internal Data :

None.



Routine NISSMR

Function :

NISSMR is the normal, round one, P-stable, E-stable match routine. PRI matching is based on the adaptive PRI window, APRIW. APRIW is non-zero only if the E-emitter has previously been matched in UNSMLR. If an update is indicated, EPRI and PPRI are averaged and APRIW is decremented by one.

Routines Called :

AMTCHDS - Angle Match Decision Subroutine.
HISSMR - Harmonic, Round 1, E-stable, P-stable Match Routine.
NUPDTSR - Normal Update Subroutine.

Locations Accessed :

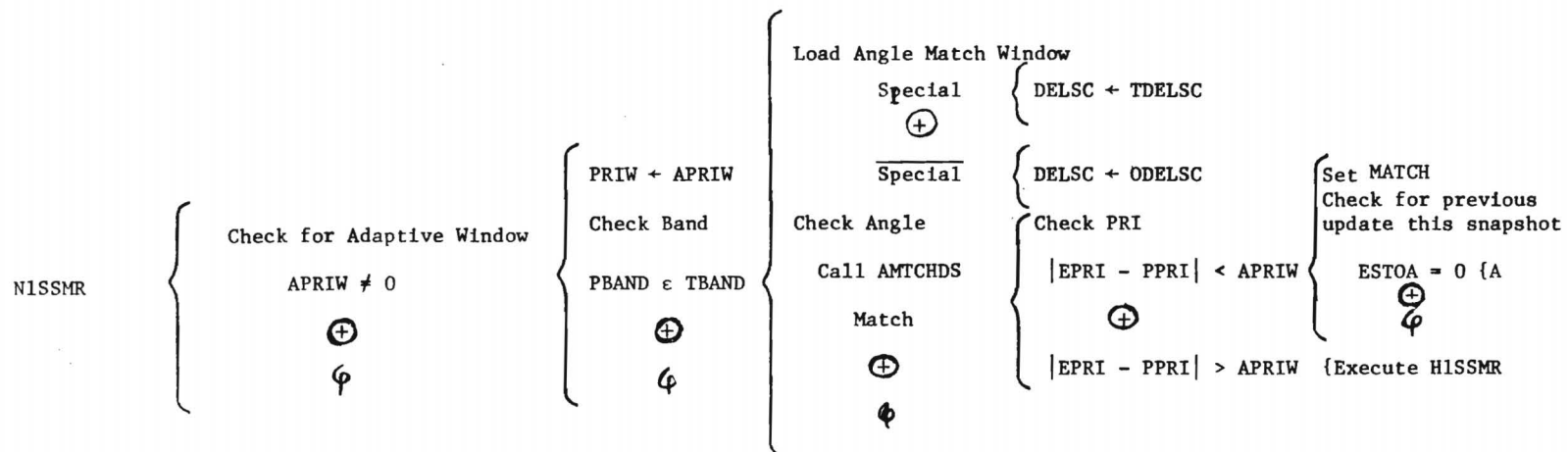
ETF : ETYPE
EPRI
ESTOA
AWPRI (EPWD, B10-B15)
Temp File : PBAND
PPRI
ETYPE Set : TRAND (EIDT4, B0-B4)
TSPECIAL (EIDT4, B5)
TDELSC (EIDT7, B8-B11)
DFF Data : ODELSC

Locations Changed :

Temp File : PPRI
ETF : ERRI
AWPRI
ETE Internal : PRIW
DELSC
MATCH

Internal Data :

None.



Ⓐ {
 EPRI ← (EPRI + PPRI)/2
 PPRI ← (EPRI + PPRI)/2
 AWPRI ← AWPRI
 Call NUPDTSR

Routine NISJMR

Function :

NISJMR is the normal, round one, P-stable, E-jittered match routine. PRI matching is based on the adaptive PRI window APRIW (computed in UNSMLR). In the event of an update decision, EPRI and PPRI are averaged and APRIW is decremented by one.

Routines Called :

AMTCHDS - Angle Match Decision Subroutine.
NUFDTSR - Normal Update Subroutine.

Locations Accessed :

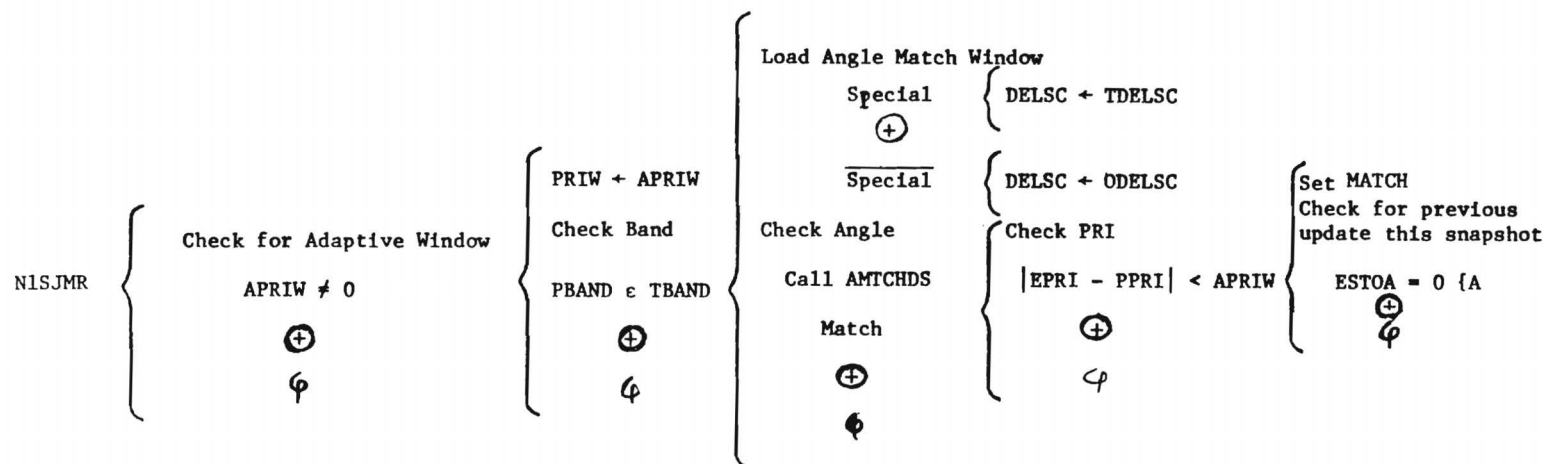
ETF : ETYPE
EPRI
ESTOA
AWPRI
Temp File : PBAND
PPRI
ETYPE Set : TBAND (EIDT4, B0-B3)
TSPECIAL (EIDT4, B8-B15)
TDELSC (EIDT7, B8-B11)
OFF Data : ODELSC

Locations Changed :

ETE Internal : PRIW
DELSC
MATCH
Temp File : PPRI
ETF : EPRI
AWPRI

Internal Data :

None.



Ⓐ {

EPRI + (EPRI + PPRI)/2

PPRI + (EPRI + PPRI)/2

AWPRI + AWPRI

Call NUPDTSR

}

Routine NIJSMR

Function :

NIJSMR is the normal, round one, P-jittered, E-stable match routine. PRI matching is based on the adaptive PRI window APRIW (computed in UNSMLR). In the event of an update decision, EPRI and PPRI are averaged and APRIW is decremented by one.

Routines Called :

AMTCHDS - Angle Match Decision Subroutine.
NUPDTSR - Normal Update Subroutine.

Locations Accessed :

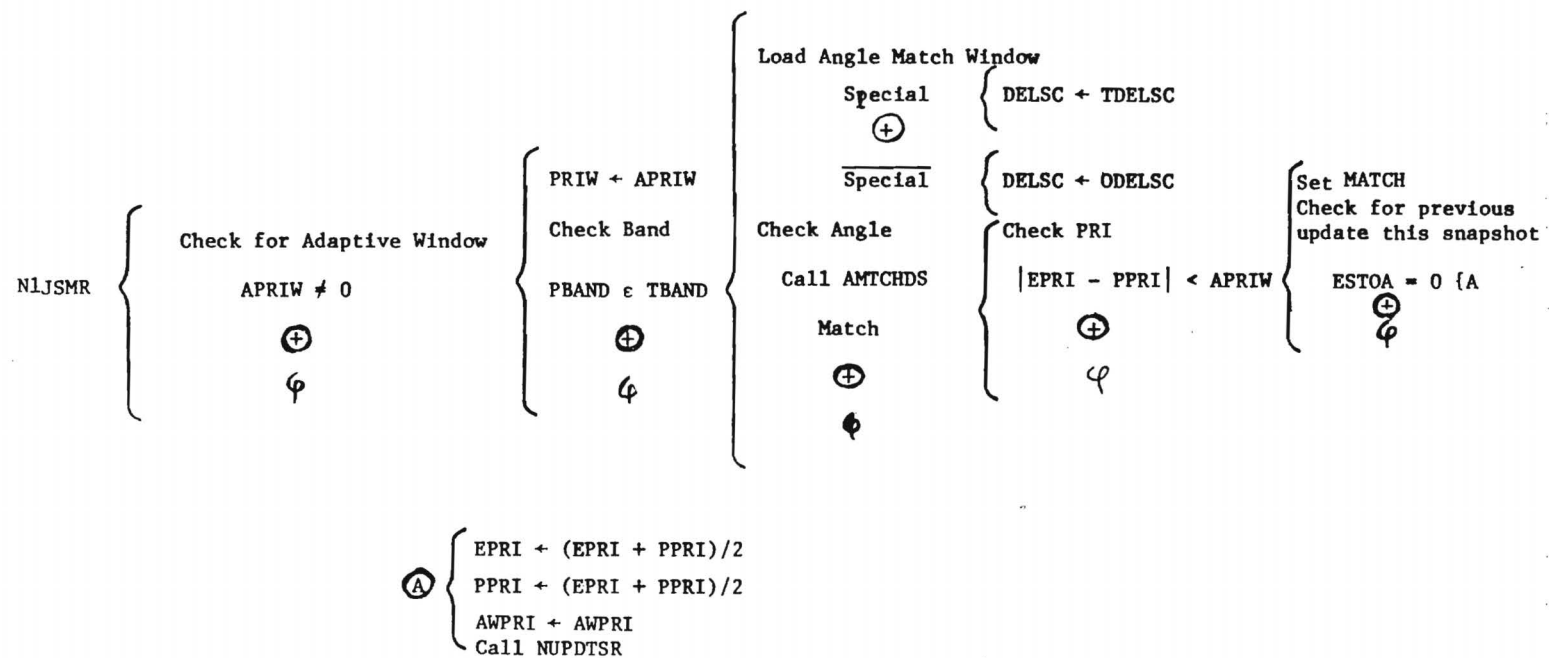
ETF ETYPE
 EPRI
 ESTQA
 AWPRI
Temp File : PSAND
 PPRI
ETYPE Set : TBAND (EIDT4, 80-B3)
 TSPECIAL (EIDT4, 88-B15)
 TDELSC (EIDT7, 88-B11)
OFF Data : ODELSC

Locations Changed :

ETE Internal : PRIW
 DELSC
 MATCH
Temp File : PPRI
ETF : EPRI
 AWPRI

Internal Data :

None.



Routine HISSMR

Function :

HISSMR is the harmonic, round 1, P-stable, E-stable match routine. Matching is on the basis of a PRI window and increment equal to the adaptive PRI window, AWPRI. AWPRI is already stored in PRIW when HISSMR is called.

Routines Called :

HRMDDS - Harmonic Match Decision Subroutine.
HUPDTSR - Harmonic Update Subroutine.

Locations Accessed :

ETE Internal : PRIW
ETF : EPRI
Temp File : PPRI

Locations Changed :

ETE Internal : LPRI
SPRI
INKR
MATCH

Internal Data :

None.

HISSMR

45

INKR ← PRIW

EPRI > PPRI

⊕

EPRI < PPRI

LPRI ← EPRI

SPRI ← PPRI

Call HRMCDS

Match

⊕

⊖

LPRI ← PPRI

SPRI ← EPRI

Call HRMCDS

Match

⊕

⊖

Set MATCH

Call HUPDTSR

Set MATCH

Routine RD2MLR - Round Two Match Loop

Function :

For each entry in the trackfile, RD2MLR calls the appropriate match routine based on the stable-jitter combination of the emitters. Match attempts continue until a match is successful or all emitters in the trackfile have been tested.

Routines called :

N2JMR - Round 2, P-jittered, E-jittered Match Routine.

Locations Accessed :

PO Control : FEMIT
 AFEMIT
ETF : JTF (EPWR, B9)
Temp File : JTFLG
ETE Internal : MATCH

Locations Changed :

None.

Internal Data :

None.

RD2MLR $\left\{ \begin{array}{l} \text{P - Jittered} \\ \oplus \\ \phi \end{array} \right.$ $\left\{ \begin{array}{l} \text{Trackfile Entry} \\ (1, E) \end{array} \right.$ $\left\{ \begin{array}{l} \text{E - Jittered} \\ \oplus \\ \phi \end{array} \right.$ $\left\{ \begin{array}{l} \text{N2JMR} \end{array} \right.$

Routine N2JJMR

Function :

N2JJMR is the normal, round 2, P-jittered, E-jittered match routine.
N2JJMR uses a PRI match window equal to 1/8 of the smaller PRI.
EPRI and PPRI are averaged in the event of a match.

Routines Called :

AMTCHDS - Angle Match Decision Subroutine.
NUPDTSR - Normal Update Subroutine.

Locations Accessed :

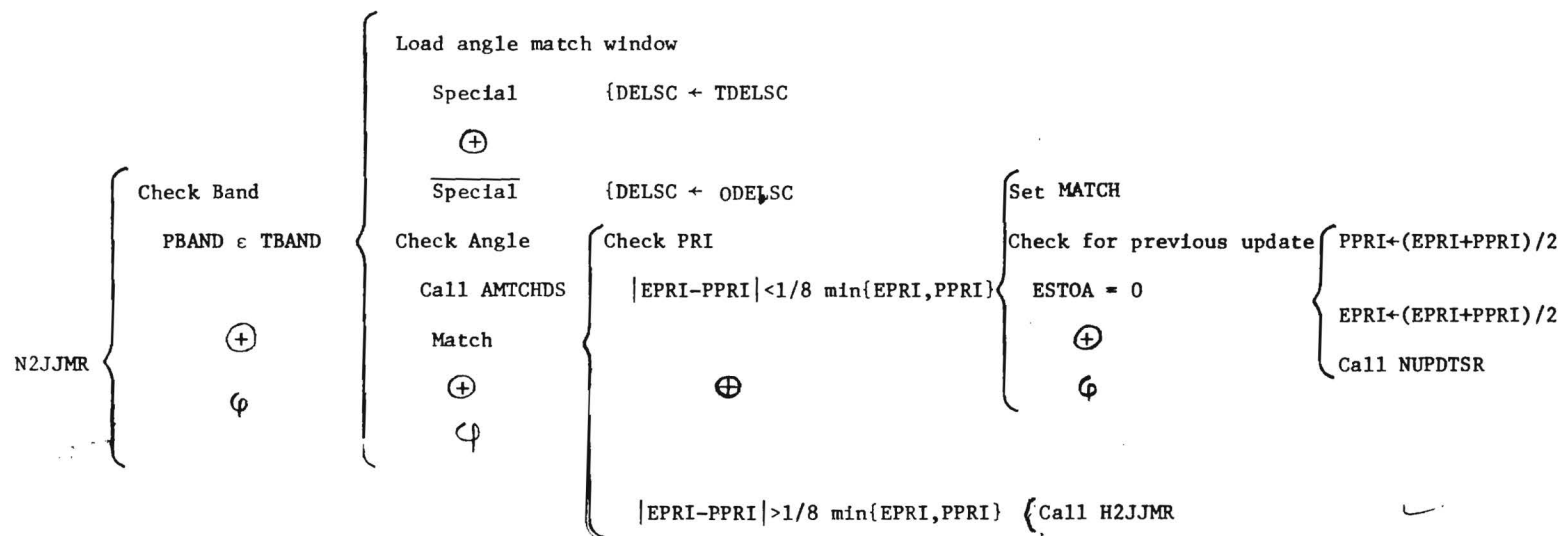
ETF : ETYPE
EPRI
ESTOA
Temp File : PBAND
PPRI
ETYPE Set : TBAND (EIDT4, B0-B3)
SPECIAL (EIDT4, B8-B15)
TDELSC (EIDT7, B8-B11)
QFP Data : QDELSC

Locations Changed :

ETE Internal : PRIW
DELSC
MATCH
Temp File : PPRI

Internal Data :

None.



Routine H2JJMR

Function :

H2JJMR is the harmonic, round 2, P-jittered, E-jittered match routine.
The match criteria are 1/8 of the smaller PRI for the PRI window
and an increment of one.

Routines Called :

HRMCDS - Harmonic Match Decision Subroutine.
HUPDTSR - Harmonic Update Subroutine.

Locations Accessed :

ETF : EPRI
Temp File : PPRI

Locations Changed :

ETE Internal : LPRI
SPRI
PRIW
INKR

Internal Data :

None.

H2JJMR

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EPRI > PPRI

⊕

EPRI < PPRI

LPRI ← EPRI
SPRI ← PPRI
PRIW ← 1/8 PPRI
INKR ← 1

Call HRMCDS

Match

⊕

⊕

Set MATCH

Call HUPDTSR

LPRI ← PPRI
SPRI ← EPRI
PRIW ← 1/8EPRI
INKR ← 1

Call HRMCDS

Match {Set MATCH

⊕

⊕

Routine UNSMLR

Function :

UNSMLR is the final match loop in ETE. Rather than using fixed PRI and angle windows, UNSMLR selects an angle window based on the difference between EPRI and PPRI, selecting a smaller window for larger PRI differences. Essentially, this allows emitters exhibiting long-term PRI instability to be matched on the basis of angle correspondence.

UNSMLR uses data stored in UNSTB in the OFP data. UNSTB Band 0 inputs and one for High Band inputs. Each table includes four PRI window - angle window pairs, selected so that the product of the windows is constant (except possibly in the case involving the largest PRI window). The largest PRI window, called the qualifying window, may be a default value in the table, a TYPE-dependent value from a separate table, or a fraction of EPRI.

Since the UNSMLR match criteria are more error prone than the match criteria in Round 0, 1, and 2, there is a larger set of pre-match checks which must be passed before an angle-PRI match is attempted. The band match criterion is more stringent than for Round 0, 1, or 2: the E-emitter must actually have been detected in PBAND in a previous intercept. The flag BPADP, in the ETYPE set is checked and, if set, no adaptive match is allowed. Optionally, depending on a flag (CKCPC in the parameter table), CEPC may be checked and the match disallowed if CEPC is greater than zero. A flag, UNSIN, is provided in the parameter table through which UNSMLR may be disabled entirely. Finally, Band 0 inputs, due to the absence of angle data, are tested purely on the basis of the PRI qualifying window. This qualifying window is typically set to a low value in the Band 0 parameter table.

Note that UNSMLR differs from the preceding match loop routines in that matching is performed within the match loop routine, rather than in a distinct match routine.

If UNSMLR produces a match, an adaptive match window is set (or updated) for the E-emitter, allowing future matches in Round 1 if the PRI drift of the emitter continues at a constant or decreasing rate.

Routines Called :

QWDRTR - Qualifying Window Retrieval Routine
UNUPDSR - Unstable Update Routine
AMTCHDS - Angle Match Decision Routine

Locations Accessed :

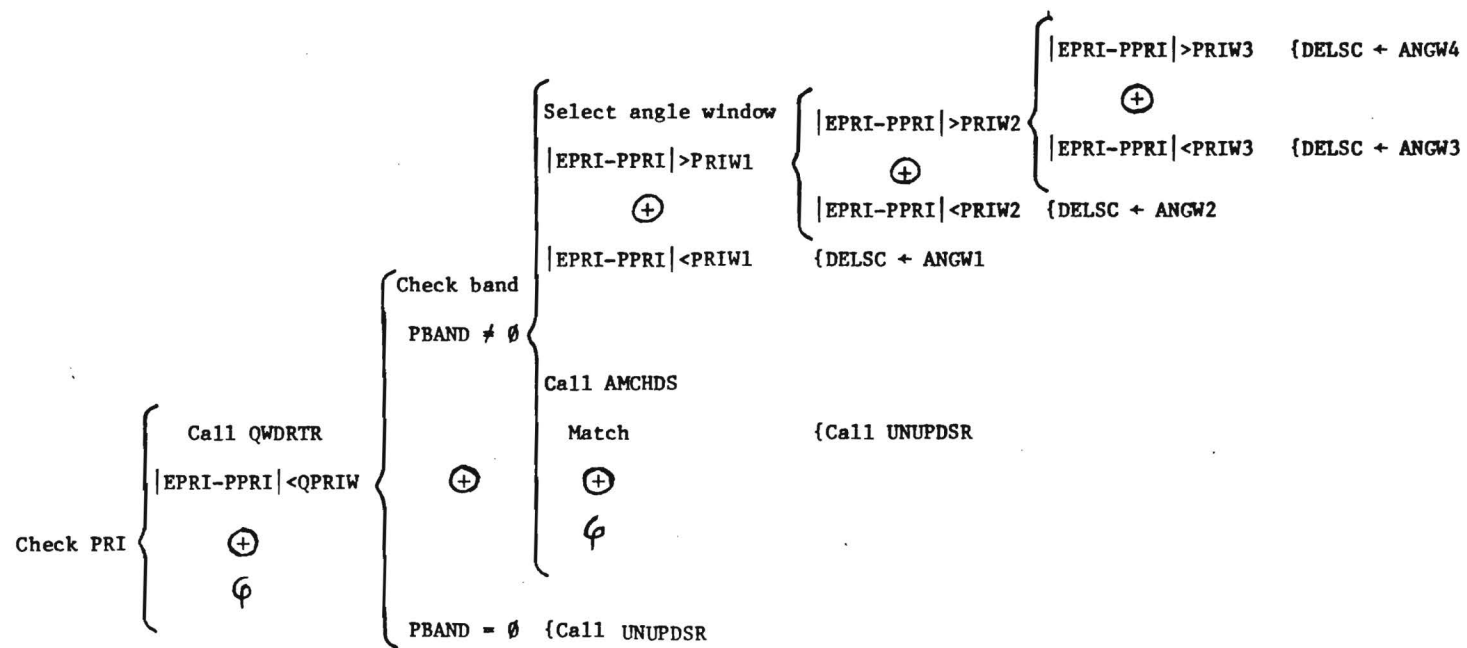
ETE Internal : MATCH
ETF : EBAND
CEPC (EAGE, B0-B2)
EPRI
EFPTR
OFP Data : UNHBTB - High Band Parameter Table
UNCDTB - CD Band Parameter Table
UNSPTB - Special Qualifying Window Table
Page 0 : FEMIT
TYPE Set : BDADP (EIDT2, B5) - Bypass Adaptive bit

Locations Changed :

ETE Internal : DELSC

Internal Data :

SP1 - Storage location for pointer to appropriate parameter table (UNHBTB or UNCDTB).



Subroutine UNUPDSR

Function :

UNUPDSR updates the adaptive PRI window following a match in UNSMLR, and executes the normal trackfile update routine, if required.

Routines Called :

NUPDTSR - Normal Update Subroutine.

Locations Accessed :

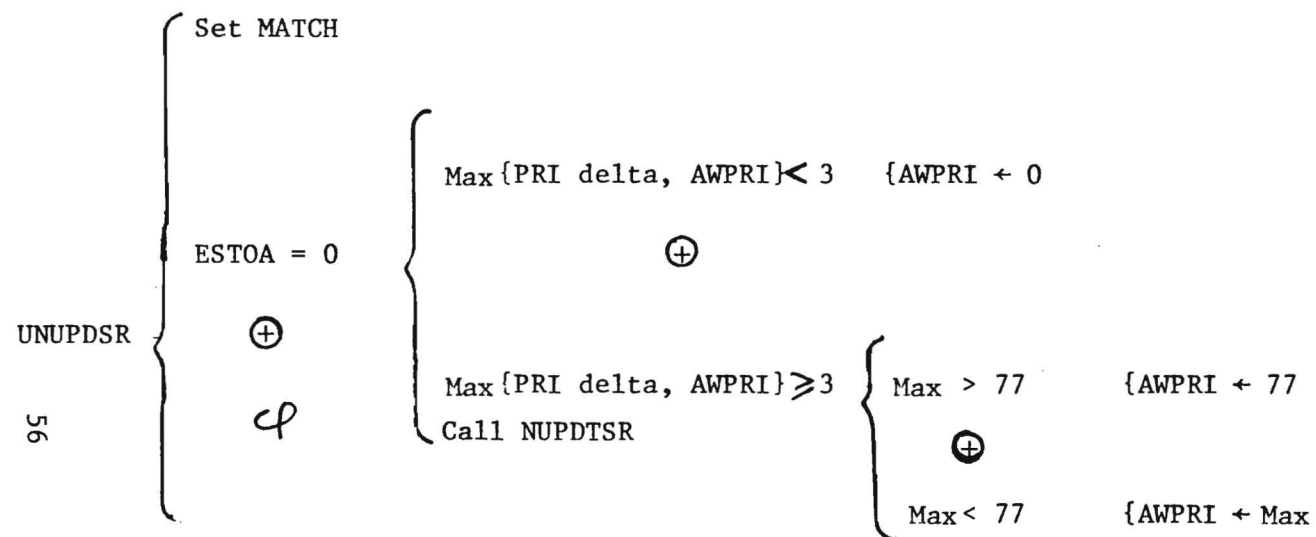
Temp File : PPRI
ETF : EPRI
 AWPRI (EPWD, B11-B15)
 ESTOA

Locations Changed :

ETE Internal : MATCH
ETF : AWPRI

Internal Data :

RTN4 - Saves return address



Routine QWDRTR

Function :

QWDRTR retrieves the PRI qualifying window used in UNSMLR. The window may be a special, TYPE-dependent value, a normal fixed value, or a fraction of EPRI. If a special value is indicated, a pointer is extracted from the ETYPE set and used to index a table of special values stored in SPWTBL in the OFD data. Otherwise GPRIW is taken from the UNSTB parameter table. Bit 0 of GPRIW indicates whether a fixed or fractional value is to be used. If bit 0 equals 0, GPRIW contains the fixed window. If bit 0 equals 1, GPRIW contains an integer, n. The window used in this case is $EPRI / 2 ** n$.

Routines Called :

None.

Locations Accessed :

ETF : EPRI
ETYP
ETYP
ETYP Set : TSPECIAL (EIDT4, B8-B15)
SPWPTR
OFD Data : SPWTBL
GPRIW

Locations Changed :

None.

Internal Data :

None.

QWDRTR { Special (ETYPE)
 58 { (+)
 { Special (ETYPE)

{ QPRIW ← SPWTBL(SPWPTR)

{ Retrieve QPRIW from UNSTB
 { QPRIW, BØ = 1
 { (+)
 { 6

{ BØ ← 0
 { n ← QPRIW
 { QPRIW ← EPRI / 2**n

Decision Subroutine AMTCHDS.

Function :

AMTCHDS is the angle match decision subroutine used by all emitter matching routines. AMTCHDS allows a default match if :

1. PBAND is band zero (thus no AOA data is available).
2. EBAND contains only band zero (that is, the emitter has not been detected in any band other than band zero, thus no AOA data is available).

A positive match decision results if both emitters have AOA data and pass the 3 match tests. AMTCHDS skips the instruction following the call in the event of a positive match decision.

Routines Called :

None.

Locations Accessed :

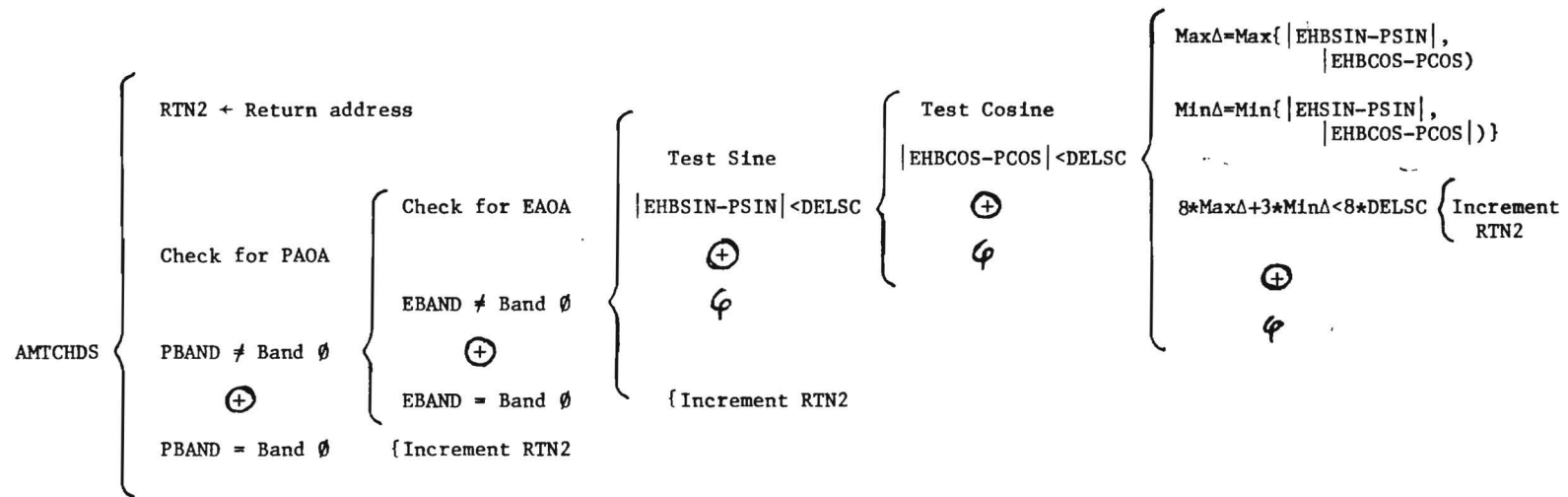
ETE Internal : DELSC
ETF : EBAND (EPWR, B0-B4)
 HBSIN (ESIN, B8-B15)
 HBCOS (ECOS, B8-B15)
Temp File : PBAND
 PSIN
 PCOS

Locations Changed :

None.

Internal Data :

RTN2 - Saves return address.



Decision Subroutine HRMCDS

Function :

HRMCDS is the harmonic match decision subroutine used in the Round 0, 1, and 2 emitter match routines. HRMCDS returns a positive match decision (indicated by skipping the instruction following the call) if

$$ABS (LPRI - (n+1) * SPRI) \leq (PRIW + n * INKR)$$

for some integer n, where LPRI and SPRI are the larger and smaller PRI, and PRIW and INKR are values stored by the calling routine prior to the call. In addition, HRMCDS returns (in scratchpad variable SV35) the value of n for which the match was achieved.

Routines Called :

None.

Locations Accessed :

ETE Internal : LPRI
 SPRI
 PRIW
 INKR

Locations Changed :

Page Control : SV35

Internal Data :

RTN2 - Saves return address.

HRMCDS

62

Initialization

RTN2 ← Return address
HRMCNT ← 0
Window ← PRIW
Difference ← LPRI-SPRI

Compute Difference
(1,n)

|Difference| ≤ Window

⊕

⊖

Increment SV35

Window ← Window + INKR

Difference ← Difference - SPRI

(Difference > Window)
⊕

{Repeat

(Difference ≤ Window)

{Skip

{Increment RTN2

3.2 Update Section

Subroutine NTEISR

Function :

NTEISR inserts a new trackfile entry following a failure to match any existing trackfile entry.

Routines Called :

TYPROSR - TYPE-dependent Priority Update Subroutine.
SCPTISR - Sine, Cosine, PRI, STOA Insert Subroutine.
RELNKSr - Trackfile Relink Subroutine.
UNLNKSr - Trackfile Unlink Subroutine
DISPDSR - Display Decision Subroutine.
ADPAGSR - Adaptive Ageout Subroutine.
INSRTDS - Insert Decision Subroutine
FMLMASR - Format Missile Launch Missile Alert Subroutine

Locations Accessed :

PO Control : FAVAL
Temp File : PPROR
 PTYPE
 PSTOA
 PBAND
 PPWR
 JTFLG
TYPE Set : TCEPC

Locations Changed :

ETF : EX
 EY
 ESIN
 ECOS
 EPWD
 EPROR
 EPWR
 ESTOA

Internal Data :

RTN2 - Saves return address.

NTEISR

29

Determine Priority

Correct MLADP

Call DISPDS

(PPROR \neq 0) \checkmark Display

⊕

Call TYPRORSR
Call FMLMASR
PPROR B5-B9 \leftarrow FPROR (Note: FPROR determined in TYPROSR)
B10-B15 \leftarrow PPWR
EPROR \leftarrow PPROR

Insert Data

Check for Room in Trackfile

ETYPE \leftarrow PTYPE
EPWR, B0-B4 \leftarrow PBAND
B9 \leftarrow JTFLG
B10-B15 \leftarrow PPWR

Call INSRTDS

Call SCPTISR
Call XYCL (Stub)
EX, B5B15 \leftarrow TX
EY, B5B15 \leftarrow TY
CEPC \leftarrow TCEPC

Insert Entry

⊕

Check CEPC

CEPC = 0

{Call ADPAGSR

⊕

Ⓢ

Check PAFLG

PAFLG = 0

{Call OLDERSR

⊕

Ⓢ

Subroutine NUPDTSR

Function :

NUPDTSR is the trackfile update subroutine executed following a straight match.

Routines Called :

YSCANSR - Scan timer update routine.
BCPTISR - Sine, Cosine, PRI, STDA Insertion Subroutine.
ADPAQSR - Adaptive Ageout Subroutine.
TYPRORSR - Fixed Priority Retrieval Subroutine.
FMLMASR - Format ML, MA Subroutine.
DISPDS - Display Decision Subroutine.
UNLNKSR - Trackfile Unlink Subroutine.
RELNKSR - Trackfile Relink Subroutine.

Locations Accessed :

Temp File : PBAND
PPROR
PPWR
JTFLG
ETF : ETYPE
E-MLADP (EPROR, B0-B3)
PROPWR (EPROR, B10-B15)
EPROR DIA
CEPC (EAGE, B0-B2)
Type Set : T-MLADP (EIDT3, B0-B3)

Locations Changed :

Temp File : PPROR
ETF : EBAND (EPWR, B-B4)
EPWR (EPWR, B10-B15)
MLTBND (EPROR, B4)
BNDSRG (EX, B0)
CEPC (EAGE, B0-B2)
CDAGE (EAGE, B11-B15)
TTRAGE (EPWD, B3-B7)
E-MLADP (EPROR, B0-B3)
MLAGE (EPWR, B5-B7)

Internal Data :

RTN2 - Saves return address.
RLNK - Significant priority change flag.

NUPDTSR

RTN 3 ← Return Address

RELNK ← 0

Update BAND Data

PBAND ≠ EBAND

⊕

φ

$$\left\{ \begin{array}{l} \text{EBAND} \leftarrow \text{PBAND} \vee \text{EBAND} \\ \text{MLTBND} \leftarrow 1 \\ \text{BNDRSQ} \leftarrow 1 \end{array} \right.$$

Update Sin, Cos, PRI, TOA

Call SCPTISR

Update Scan Timer

Execute YSCANSR

Update CEPC

CEPC ≠ 0

⊕

φ

CEPC ← CEPC - 1

CEPC = 0

⊕

φ

(Call ADPAGSR

Update Age Counters

CEPC = 0

⊕

φ

PBAND = Band φ (CDAGE ← φ

⊕

PBAND ≠ Band φ (TTRAGE ← φ

Update Priority, Power, Jitter

Call TYPRORSR

Call FMLMASR

Correct EMLADP

EMLADP ← EMLADP ∧ TMLADP (ETYPE)

NUPDTSR
(Continued)

Update MLAG

EMLMA > PMLMA

⊕

EMLMA = PMLMA

⊕

EMLMA < PMLMA

PML = 1 { MLAG ← 0

⊕

φ

EMLMA ≠ 0 { MLAG ← 0

⊕

φ

MLAG ← 0

RELNK ← 0

Check for Display

Call DISPDS

PPROR = 0 ∧ Display

RELNK ← 1

EPROR ← 0

⊕

Update MLADP

EPAN ← PPAN

PPROR ← PPROR ∨ EPROR (Note: PPROR contains only MLADP at this point)

PPROR ≠ 0 ∨ Display

Check EPROR

EPROR ∧ B2 = 0

⊕

EPROR ∧ B2 ≠ 0

Insert Power, Fixed priority, jitter

PPROR, B5-B9 ← PPROR

B10-B15 ← PPWR

EPROR ← PPROR

EPWR, B9 ← JTFLG

B10-B15 ← PPWR

RELNK ← 1

PBAND ≠ 0

⊕

φ

Update Power fields

MSPWR ← Max {MSPWR - 1, PPWR}

Check for significant power change

MSPWR - PRPWR > DELPRO { PRPWR ← MSPWR
RELNK ← 1

⊕

φ

89

NUPDTSR
(Continued)

Reorder Trackfile

RELNK

Call UNLNKSR

⊕

Call RELNKSR

φ

Subroutine HUPDTSR

Function :

HUPDTSR is the update subroutine called following a harmonic match. TYPE and TYPE-dependent fields are changed in HUPDTSR, and measurement data is updated.

Routines Called :

TYPRORSR - TYPE-dependent Priority Update Subroutine
(Note: returns corrected MLADP in PPROR and fixed priority in FPROR).
SCPTISR - Sine, Cosine, PRI, STOA Insert Subroutine.
RELNKSr - Trackfile Relink Subroutine.
DISPDSR - Display Decision Subroutine.
FMLMASR - Format Missile Launch, Missile Alert Subroutine.
UNLNKSr - Trackfile Unlink Subroutine.

Locations Accessed :

Temp File : PTYPE
PPROR
PBAND
JTFLG
PPWR
ETE Internal : FPROR

Locations Changed :

ETF : ETYPE
TYPRR (EPROR, B5-B9)
PROPWR (EPROR, B10-B15)
MLADP (EPROR, B0-B4)
EBAND (EPWR, B0-B4)
JTF (EPWR, B9)
MLTBND (EPROR, B4)
BDRSRQ (EX, B0)

Internal Data :

RTN2 - Saves return address.

HUPDTSR

Update Band Data

PBAND \neq EBAND⊕
φ
$$\left\{ \begin{array}{l} \text{EBAND} \leftarrow \text{EBAND} \vee \text{PBAND} \\ \text{MLTBND} \leftarrow 1 \\ \text{BNDRSQ} \leftarrow 1 \end{array} \right.$$

Change TYPE

ETYPE \leftarrow PTYPE

Check for Display

Call DISPDSR

(PPROR \neq 0) Display

⊕

(PPROR = 0) \wedge Display
$$\left\{ \begin{array}{l} \text{Call TYPRORSR} \\ \text{Call FMLMASR} \\ \text{Correct MLADP} \\ \text{Update Priority} \\ \text{EPAN} \leftarrow \text{PPAN} \\ \text{PPROR} \leftarrow \text{PPROR} \vee \text{EPROR}, \text{B0-B4} \\ \text{PPROR}, \text{B5-B9} \leftarrow \text{FPROR} \\ \text{B10-B15} \leftarrow \text{PPWR} \\ \text{EPROR} \leftarrow \text{PPROR} \end{array} \right.$$
{EPROR \leftarrow 0

Update Sin, Cos, PRI, STOA

Call SCPTISR

Update Power, Jitter

$$\begin{array}{l} \text{JTFD} \leftarrow \text{JTFLG} \\ \text{EPWR}, \text{B10-B15} \leftarrow \text{PPWR} \end{array}$$

Call UNLNKSR

Call RELNKSR

Decision Subroutine INSRTDS

Function :

INSRTDS decides if a new record based on the P-emitter may be created and inserted into ETF. Insertion is allowed if a record block is available, or the priority of the candidate is greater than that of the current lowest + PRDEL. In the first case, the new emitter record is written on the first available block and inserted into ETF by RELNKSR. In the second, the last entry in ETF is overwritten; UNLNKSR extracts it from the ETF list and RELNKSR repositions it according to the priority of the new emitter.

Routines Called :

RELNKSR - Record Insertion Subroutine
UNLNKSR - Record Removal Subroutine.

Locations Accessed :

ETF : RELPRR (EPROR, B0-B1, B5-B15) - priority value used
to determine the position
of an entry in ETF.
Page 0 : FAVAL
AFAVAL
AFEMIT - pointer to the last record in ETF
Temp File : PPROR

Locations Changed :

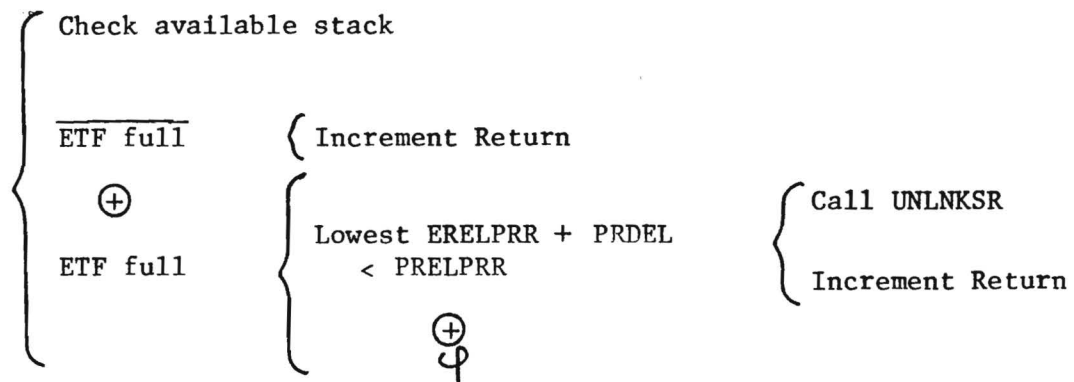
None

Internal Data :

RTN3 - Saves the return address

INSRTDS

72



Subroutine DISPDSR

Function :

DISPDSR assimilates TYPE set data and current setting on the cockpit control panel to determine whether an intercept bearing none of the ML, MA, DIA, or PAN conditions should be displayed. Display occurs if any of the following conditions exist:

1. ETYPE is a known type.
2. ETYPE is an unknown type and the UNKNOWN button is pushed.
3. ETYPE is a search type and the SEARCH button is pushed.

DISPDSR skips the instruction following the call if the emitter is to be displayed.

DISPDSR receives a pointer to the emitter record for which a display decision is desired in AC2.

Routines Called :

None

Locations Accessed :

ETF : ML (EPROR, B0)
MA (EPROR, B1)
DIA (EPROR, B2)
PAN (EPROR, B3)
TYPE set : UK (EIDT3, B7) - Unknown Flag
EID# (EIDT4, B8-B11) - Indicates status of ETYPE - normal,
unknown, or search.
Page 0 : UKTGF - Unknown Toggle Flag
IPFLG - Search Flag

Locations Changed :

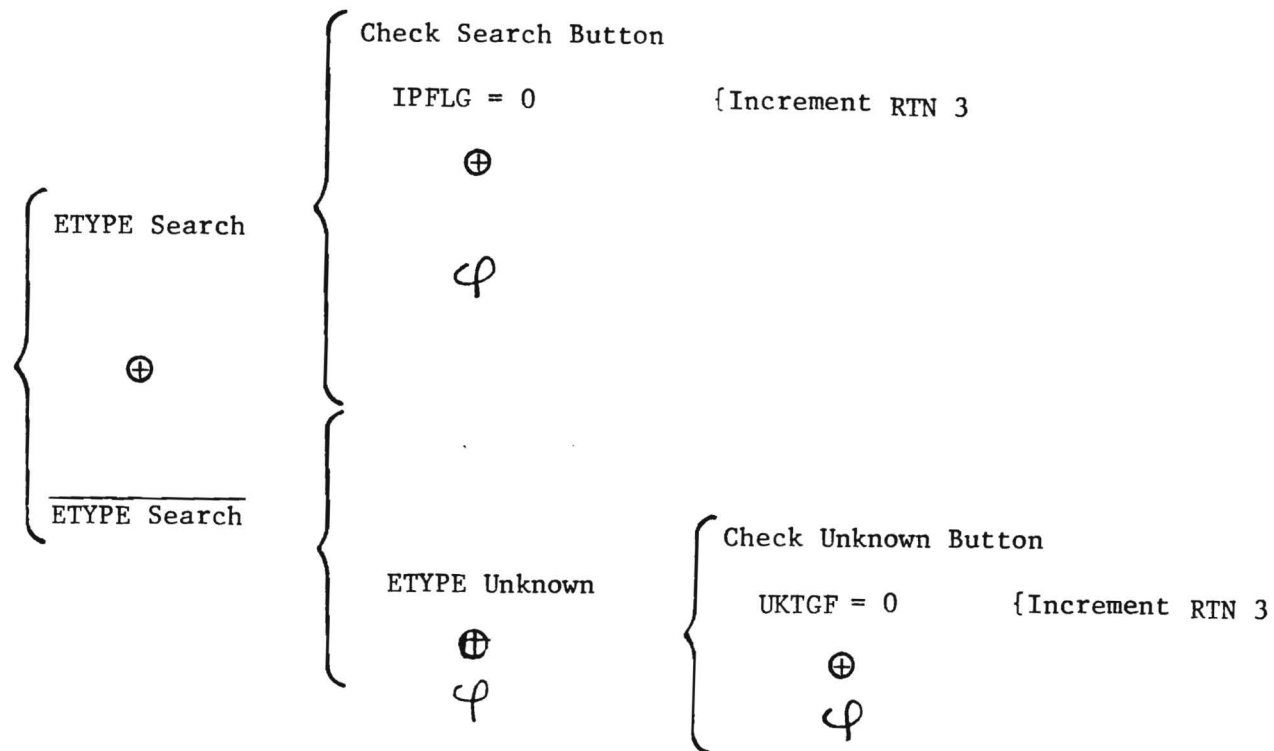
- None

Internal Data :

None.

DISPDSR

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Subroutine TYPRORSR

Function :

TYPROR extracts the fixed priority value, which depends on emitter type and altitude of the aircraft, from the High/Low table and stores it in FPROR.

A pointer to the emitter record for which the fixed priority is desired is passed in AC2.

Routines Called :

None

Locations Accessed :

ETF : ETYPE
Page 0 : MODE, B12 - altitude switch
TYPE set : PRY (EIDT1, B5-B9) - Index to High/Low table
OFF Data : HLTAB - High/Low table; contains TYPE dependent fixed priority values

Locations Changed :

ETE Internal : FPROR

Internal Data :

RTN3 - Saves return address

TYPRORSR

76

Retrieve High/ Low word

MODE,B12 = 1 { FPROR ← right byte

⊕

MODE,B12 = 0 { FPROR ← left byte

Subroutine ADPAGSR

Function :

ADPAGSR, the adaptive ageout routine, attempts to purge the track-file of multiple entries which have been generated by a single emitter.

ADPAGSR is called when the CEPC (Candidate Emitter Promotion Count) of a particular entry becomes 0, indicating that the entry has achieved enough matches to substantiate its validity. Each trackfile entry is compared to that with a newly zero CEPC and aged (CDAGE and TTRAGE increased to AGEOT-1) if the PRI difference is less than or equal to DELPRI and agreement in at least one band exists. Hence, the suspected invalid records are deleted if not matched in the next measurement cycle.

ADPAGSR receives a pointer to the record having a newly zero CEPC IN AC2.

Routines Called :

None

Locations Accessed :

ETF	:	EFPTR
		EPRI
		EBAND (EPWR, B0-B4)
		ETYPE
Temp File	:	PTYPE
		PPRI
		PBAND
TYPE set	:	AGEOT(EIDT2, B8-B11) - Age limit for both CDAGE and TTRAGE
QFP Data	:	DELPRI - Smallest significant PRI difference

Locations Changed :

ETF	:	CDAGE (EAGE, B11-B15) - Time passed since last band zero intercept
		TTRAGE (EPWR, B3-B7) - Time passed since last high band intercept

Internal Data :

RTN3 - Saves return address.
ADPAGPT - Pointer used to traverse ETF list

ADPAGSR

78

{ Trackfile Entry
(1, EOF)

{ PRI Δ < DELPRR
⊕
φ

{ Band Match
⊕
φ

{ CDAGE ← AGEOT - 1
TTRAGE ← AGEOT - 1

Subroutine YBCANSR

Function :

YBCANSR maintains a timer controlling the frequency with which the scan rate measurement is performed for those emitters whose TYPE set tables contain the Scan Required flag.

YBCANSR, as part of the normal update, increments SCAN CNT, TAG upon each intercept of a particular emitter, but not to exceed 6. If SCAN CNT, TAG is 7 on entrance, YBCANSR stores PBAND, a needed parameter for the scan rate measurement routine (outside ETE), in SCFLQ, thereby preserving the raw sine and cosine values in SCSIN and SCCOS respectively (see ETEO). Also, SCAN CNT, TAG is incremented to 8 in this case.

YBCANSR receives a pointer to the emitter currently being updated in AC2.

Routines Called :

None

Locations Accessed :

ETF : SCANTMR (EAGE, B4-B7) - timer for the scan rate
measurement routine
TYPE set : SR(EIDT3, B5) - Scan Required Flag; set if SCANTMR
must be maintained by ETE.
Temp File : PBAND
Page 0 : SCFLQ - Storage location for the band parameter used
in the scan rate measurement routine

Locations Changed :

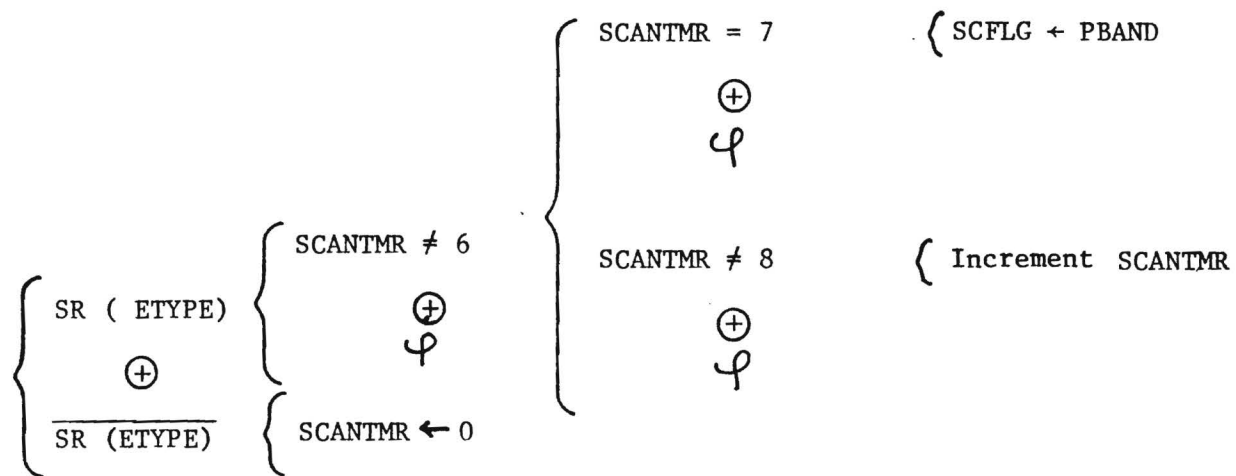
ETF : SCANTMR
PAGE 0 : SCFLQ

Internal Data :

RTN3 - Saves return address

YSCANSR

08



Subroutine OLDERSR

Function :

OLDERSR fixes each of the band-related ages, CDAGE and TTRAGE, in a dubious entry to the greater of AGEOT/2 and the current value.

An increase in age corresponds to a decrease in the time left for an entry to remain unmatched in the trackfile.

OLDERSR receives a pointer (in AC2) to the entry to be (conditionally) aged.

Routines Called :

None

Locations Accessed :

ETF : CDAGE (EAGE, B10-B15) - Time passed since last
band 0 intercept.
TTRAGE (EPWD, B3-B7) - Time passed since last high
band intercept.
TYPE set : AGEOT (EIDT3, B8-B11) - Age limit for both CDAGE and TTRAGE

Locations Changed :

ETF : CDAGE (EAGE, B10-B15)
TTRAGE (EPWD, B3-B7)

Internal Data :

RTN3 - Saves return address

OLDERSR

82

$$\left\{ \begin{array}{ll} \text{CDAGE} < \text{AGEOT}/2 & \{ \text{CDAGE} \leftarrow \text{AGEOT}/2 \\ \oplus & \\ \varphi & \\ \text{TTRAGE} < \text{AGEOT}/2 & \{ \text{TTRAGE} \leftarrow \text{AGEOT}/2 \\ \oplus & \\ \varphi & \end{array} \right.$$

Subroutine SCPTISR

Function :

SCPTISR inserts the P-parameters sine, cosine, ADA,
and PRI into the trackfile.

Routines Called :

None

Locations Accessed :

Temp File : PPRI
 PSIN
 PCDS
 PSTOA
 PBAND

Locations Changed :

ETF : EPRI
 HBSIN
 HBCOS
 ESTOA

Internal Data :

RTN3 - Saves return address

SCPTISR

84

Insert PRI and TOA

EPRI \leftarrow PPRI

ESTOA \leftarrow PSTOA

Check for Band \emptyset

PBAND \neq Band \emptyset

\oplus

φ

HBSIN \leftarrow PSIN

HBCOS \leftarrow PCOS

Subroutine RELNKS

Function :

RELNKS determines the correct position of an emitter record in the ETF priority ordering and inserts it into the list accordingly.

The priority value on which the ordering is based is obtained from a subset of the data fields in the EPROR (or PPROR) word. These fields are, in decreasing order of influence, ML, MA, PRIOR, And PPWR.

RELNKS assumes that the emitter to be inserted into ETF is the P-emitter and that the record will be or is written at the current first available block. Therefore, RELNKS updates FAVAL to point to the next block on the available stack.

Routines Called :

None

Locations Accessed :

ETF	:	EFPTR	
		EPROR	
		RELPRR	- Priority value used to determine the position of an entry in ETF
Page 0	:	FEMIT	
		AFEMIT	
		FAVAL	
Temp File	:	PPROR	
		RELPRR	

Locations Changed :

ETF	:	EFPTR
Page 0	:	FEMIT
	:	AFEMIT
	:	FAVAL

Internal Data :

RTN3 - Saves return address
PRVPT - Saves previous pointer
ETFREC - Saves address in AC2

RELNKSR { Trackfile Entry { Update ETF links
 (1, P-RELPRR > E-RELPRR \vee EOF)

Subroutine UNLNKSR

Function:

UNLNKSR deletes an emitter record from the ETF linked list structure. The data written on the record block of the deleted entry is not affected by UNLNKSR.

A pointer to the record to be deleted is passed in AC2. The record block becomes the "top" of the available stack, and FAVAL is updated accordingly.

Routines Called :

None

Locations Accessed :

ETF	:	EFPTR
Page 0	:	FEMIT
		AFEMIT
		FAVAL

Locations Changed :

ETF	:	EFPTR
Page 0	:	FEMIT
		AFEMIT
		FAVAL

Internal Data :

RTN3 - Saves return address

UNLNKSR

{ Trackfile Entry
(1, entry found)

{ Update ETF links

Subroutine FHLMASR

Function :

FHLMASR conditionally augments the missile launch/alert information carried in PPROR on entrance to ETE according to TYPE set data.

FHLMASR insures that MA is set if fixed priority is 37, and that ML is set if both the MAEML and MA flags are present.

FPROR, the fixed priority, is passed to FHLMASR in AC2.

Routines Called :

None.

Locations Accessed :

Temp File : P-ML (PPROR, B0)
P-MA (PPROR, B1)
PTYPE

TYPE set : MAEML(EIDT3,B9) - Flag for the condition that missile alert and missile launch are indistinguishable.

ETE Internal : FPROR - Fixed TYPE set priority

Locations Changed :

Temp File : P-ML
P-MA

Internal Data :

RTN3 - Saves return address.

FMLMASR

06

Check for priority 37

FPROR = 37 { PMA ← 1

⊕

φ

Check for ML, MA indistinguishable

MAEML (PTYPE)

PMA = 1

{ PML ← 1

⊕

φ

⊕

φ

FINAL ENGINEERING REPORT

ETE RESTRUCTURING PROJECT, PHASE I

PREPARED BY

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ROBINS AIR FORCE BASE
F09603-78-G-4368-0004

FOREWORD

The ETE Restructuring project under Contract F09603-78-G-4368, Tasks 0004 and 0015, was conducted by the Engineering Experiment Station at Georgia Tech. This report is the Final Report for Task 0004, administered under Georgia Tech Project A-2259 by the EW System Software Branch of the Defense Systems Division, Systems Engineering Laboratory.

The Georgia Tech Project Director was Mr. M. Andrew Lipscomb. The project was under the direct supervision of Mr. Thomas M. Miller, division chief, and the general supervision of Mr. R. P. Zimmer, laboratory director. Mr. Harry Jennings was the project monitor at Warner Robins Air Logistics Center.

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1.0 Summary

This report describes a study conducted by the Georgia Tech Engineering Experiment Station for the United States Air Force, Warner Robins Air Logistics Center (WR-ALC) to determine the technical and economic feasibility of rewriting an existing computer program to produce a functionally equivalent program in a more maintainable form. Maintainability, as applied to computer software, refers to the ease with which a program can be modified in response to changing requirements of the program user. WR-ALC has responsibility for such maintenance on a variety of Electronic Warfare (EW) systems. Software engineering techniques, such as structured programming and modular design, are available for enhancing software maintainability; it is often assumed, however, that such techniques tend to degrade software efficiency in terms of core memory utilization and execution. In order to test this assumption, WR-ALC engineers outlined the following task to be performed by Georgia Tech:

1. Develop procedures for restructuring an existing computer program to produce a functionally equivalent program of higher maintainability.
2. Apply these procedures to the Emitter Trackfile Entry (ETE) module of the AN/ALR-46 Operational Flight Program as a test case.
3. Determine differences in core memory utilization and execution time between the original and restructured versions.

In addition to these technical points, EES was required to report the effort expended in the restructuring project in terms of a work measure which may be employed to predict level of effort vs. program size for restructuring tasks of similar scope. This measure is for use by WR-ALC in determining the economic feasibility of restructuring in an operational setting.

The following results were obtained:

1. Core memory utilization in the restructured version increased by approximately 25%.

2. Execution time for the restructured version decreased by an average of approximately 30%.
3. The effort required, stated in terms of lines of original code per man-day was:

For the specification and analysis phase	5.8 lines/day
For the development and validation phase	9.6 lines/day
Total Effort	3.6 lines/day

A large portion of the increase in core memory utilization is attributable to the policy adopted for purposes of the study, of providing maximum separation of function in the software design in accord with the goal of high maintainability. In an operational environment, a more balanced design could yield an acceptable level of functional separation without such a large penalty in core memory. In view of the substantial decrease in execution time, it is concluded that restructuring is a technically feasible option for increasing maintainability.

The level of effort required compares favorably to the effort required to develop new software from scratch. The development and validation cost is approximately the same as the accepted industry average. Industry figures on the cost of requirements analysis and specification for new software are difficult to obtain and interpret, but it is unlikely that a specification of comparable scope and detail could be developed with less effort than was required for the restructuring. Furthermore, substantial portions of the analysis required for restructuring can be conducted by persons with little prior experience in EW software. Restructuring by inexperienced personnel can decrease the monetary cost of the effort and does not divert experienced personnel from the ongoing maintenance efforts on the operational software.

On the basis of these and other conclusions it is recommended that restructured software be given a field trial to determine more precisely the extent to which maintainability is enhanced. Studies aimed at determining the technical feasibility of conversion to a higher order language, improving system reliability, and formulating long range maintenance plans are also recommended.

2.0 Project Documentation

The ETE restructuring project encompassed a number of subtasks which

have been documented in separate reports. These are listed below with a summary of the contents of each. The present report contains the results of the efficiency comparisons, the level of effort report, and various conclusions and recommendations drawn from the test results, and the experience of the project team in conducting the work. The reports listed below were prepared under two tasks on Contract No. F09603-78-G-4368. The task number is given in parentheses following the report title.

- . CPCI Computer Program Development Specification for the Emitter Trackfile Entry Module of the ALR-46 Operational Flight Program (0004).

This document contains the functional specification for the restructured ETE module. It contains a description of the functional requirements on ETE, and defines the principle modules in the implementation.

- . CPCI Computer Program Product Specification for the Emitter Trackfile Entry Module of the ALR-46 Operational Flight Program (0004).

This document contains the detailed design specification for the restructured ETE module. The specification is organized on the basis of the program modules and includes, for each module, a functional summary, a list of data accessed and modified, and a Warnier-Orr chart illustrating the module's organization.

- . CPCI Computer Program Development Test Plans/Procedures (0004).

This document describes the procedures and test environment used in the execution time comparison tests. It describes the driver software developed to exercise ETE and defines the benchmark test cases to be used in the testing.

- . Final Engineering Report, ETE Restructuring Project, Phase II (0015)

This report documents the procedures developed for the restructuring and benchmark test cases used in the comparative testing. The test cases are related to specific functions in ETE. Execution time results are given in each case.

3.0 Effect of Restructuring on Program Efficiency

The results of the core memory and execution time efficiency compari-

sons are provided in Table 1.

The execution time figures in Table 1 give the range of differences measured between the two versions and the mean difference for the 23 benchmark tests (equally weighted). As described in the test case documentation, Task 0015 Final Engineering Report, timing accuracy in the execution time measurements were limited by instabilities in the system real time clock. The high value reported for each figure represents a best estimate. Test results for individual cases are reported in the test case documentation.

4.0 Level of Effort

Table 2 shows the time in hours and, where applicable, hours per line of original code devoted to the ETE restructuring task, broken down by subtask and by category of personnel contributing to the effort. The figures represent only the time devoted specifically to technical aspects of the project. Administrative tasks are excluded. Time spent in the preparation of documents is included for documents, such as the specifications, which are part of the permanent documentation of the software. Time spent in the preparation of other documents, such as the Final Engineering Report, which are not normally part of a software development effort is excluded. The figures include technical services, such as drafting, but exclude secretarial services.

The total effort is broken into four subtasks: Software Development, Development of Procedures, Development of Test Driver, and Evaluation.

Software Development is further decomposed into Functional Specification, Design Specification, and Coding and Validation. The Functional Specification and Design Specification subtasks include all the analysis efforts expended in the preparation of the documents. In particular, the Functional Specification subtask includes time spent in the review of existing documentation and the initial analysis of the software being restructured. The Coding and Validation subtask includes time spent in the preparation of documentation relevant to this phase of the effort.

Development of Procedures includes all time spent in researching and documenting the Restructuring Procedures. The time required in this effort is independent of the scope of the restructuring, thus the "hours per line" figure is not applicable.

Development of the Test Driver includes only the fixed effort asso-

Minimum improvement	13%
Maximum improvement	49%
Mean improvement	30%

Table 1. Improvement in Execution Time
in Restructured ETE

ciated with this task, for example, the initial design and development effort and the effort expended in modifying the driver to perform timing measurements. Effort expended in performing the minor modifications required for each run of the driver is included, as applicable, with the Coding and Validation or Evaluation figures.

The Evaluation subtask includes the time spent developing the Comparative Test Plan and test data, and the time spent in conducting the comparative tests.

The categories of personnel listed are Engineers, Graduate Research Assistants and undergraduate Student Assistants. Graduate Research Assistants normally performed at the level of professional programmers, and Student Assistants performed technical support tasks such as drafting and data gathering.

5.0 Conclusions

The following subsections contain the principle conclusions drawn from the restructuring study. These conclusions are drawn from both the specific data presented in the previous section, and the general experience of the project team in performing the restructuring.

5.1 Technical Feasibility

The observed increase in core memory utilization is, in part, attributable to the relative priority of design goals adopted by the project team for purposes of the study. The project Statement of Work requires the production of a restructured program of equivalent specification. Since the objective of the project was primarily to evaluate the effects of structured, modular programming, the project team adopted a somewhat conservative interpretation of this requirement. Design changes in the restructured program were purely structural and organizational in nature; there were no changes in the basic processing algorithms implemented in the program.

At the detailed design level, design goals were stated in terms of functional separation (a maintainability characteristic), execution time efficiency, and core memory efficiency. Design tradeoffs arise most frequently from conflicts between requirements for functional separation and core memory efficiency. In keeping with the project objective of enhanced maintainability, functional separation was given highest priority. Since

Table 2. Summary of Effort Expended

	Engineer		Graduate Research Assistant		Student Assistant		Total	
	hours	hrs./line	hours	hrs./line	hours	hrs./line	hours	hrs./line
I. Software Development Total	1470	1.12	930	.71	510	.39	2910	2.22
A. Functional Specification	720	.55	690	.53	410	.31	1820	1.39
B. Design Specification	350	.27	0	0	100	.08	450	.34
C. Coding and Validation	400	.30	240	.18	0	0	640	.49
II. Development of Procedures	240	N/A	0	N/A	0	N/A	240	N/A
III. Development of Test Driver	40	N/A	70	N/A	0	N/A	110	N/A
IV. Evaluation	180	.09	40	.03	0	0	220	.12
TOTAL	1930	N/A	1040	N/A	510	N/A	3480	N/A

core memory efficiency was least compatible with this primary goal, it was given lowest priority. Execution time efficiency was given secondary priority.

It is reasonable to expect that, in a more balanced approach, the increase in core use could be lessened somewhat, although probably not eliminated, without incurring substantial penalties in either execution time or maintainability.

In view of the decrease in execution time in the restructured version it is safe to conclude that restructuring is a technically feasible option for increasing software maintainability.

5.2 Economic Feasibility

Conclusions regarding the economic feasibility and desirability of restructuring must ultimately be drawn by WR-ALC personnel, but several points from the study are noteworthy in this regard.

The economics of restructuring actually involves two questions. First, is any sort of broad scope revision desirable? Secondly, if a major revision is to be undertaken, what is the appropriate approach? The current study does not address the question of economic desirability of a revision, as such. This question will require determination of the relative cost of maintaining revised software as opposed to continuing in the current operating mode. Tentative conclusions can be drawn, however, with regard to the relative economy of restructuring versus other approaches to revision.

The most frequently suggested alternative to restructuring is redeveloping; that is, developing new software directly from the requirements without reference to the existing code. Any software development effort requires two phases: a requirements analysis phase terminating in a functional specification for the software and a design and development phase wherein the functional specification is translated into operational code. Restructuring differs from redeveloping only in the requirements analysis phase; given an adequate functional specification the design and development phase is the same for both.

Any attempt to develop a thorough functional specification without reference to the existing code will necessarily require an extensive commitment of time by personnel with an intimate knowledge of the system's develop-

ment history. It has been the project team's experience that existing published documentation (as opposed to the private notes of the system engineers) is inadequate for software development. Restructuring, on the other hand, requires very little commitment of time from experienced personnel. None of the Tech personnel involved in the restructuring project had prior experience on the ALR-46 software. Although the project team frequently required consultation with WR-ALC engineers, the interchange usually consisted of focused question and answer sessions. The commitment of time by WR-ALC engineers was small compared to the total effort.

Since the diversion of experienced personnel is expensive both directly and in terms of the effort lost in the normal activities of operational software maintenance, it is safe to conclude that any revision effort should begin with analysis of the existing code. This is not to say the requirements analysis should not extend beyond the existing code, but the restructuring team will be better prepared for such extended analysis and efficient interchange with other personnel after an initial analysis of the existing code.

5.3 Effects of Scope on the Restructuring Effort

A significant portion of the ETE code performs operations which are more closely related to the function of modules external to ETE than to that of ETE itself. This sort of functional mixing is likely to be found in any program with a long history of modification. This being the case, broad restructuring efforts are likely to yield greater benefits in efficiency and maintainability than narrow ones.

On the other hand, as the current study indicates, restructuring at the level of primary modules can yield a significant payoff. Since piecemeal restructuring requires fewer personnel and implies less disturbance to the ongoing task of maintaining operational software, this approach may be preferable, at least in the early stages of a revision effort. A significant result from the current study is that the bulk of the effort in the restructuring lies in the requirements analysis phase. If this analysis is performed well initially, and design documentation is maintained during operational maintenance, then further revisions at a later date will be less costly.

5.4 Adequacy of the Restructuring Procedures

In the development of procedures for the restructuring, the principle

goal was to define design, testing, and documentation procedures which would remain valid in an operational setting. The procedures which evolved satisfy most requirements of good practice, that is, they provide sound design information and traceability of requirements. Nonetheless, they should be considered as prototypical rather than final. Experience in actual operations will undoubtedly reveal opportunities for providing better information, or providing it more efficiently. In particular, some of the more burdensome activities associated with documentation development are subject to automation.

5.5 Reliability Effects of Restructuring

Restructuring can lead to significant gains in software reliability. The team's experience indicates that reliability is enhanced in three ways.

First, the in-depth analysis required to produce the Functional Specification provides a means of detecting problems in the existing design. A number of design anomalies were discovered in the original version of ETE and resolved in the restructuring.

Secondly, the design procedures employed in the effort lead to a high level of programmer efficiency (which is defined here as inversely proportional to the rate at which a programmer or designer introduces errors into the software). The great majority of modules passed validation testing in no more than three runs. A significant portion of the modules passed in one run, that is, no errors were detected.

Thirdly, the structured design procedures allowed the formulation of explicit test plans and test coverage measures for the detection of those errors which were introduced. The formal testing procedures, coupled with an informal review process, were highly effective in eliminating errors. It is impossible to say with certainty what percentage of the total errors in the program were detected since the number of undetected errors is not known. It is noteworthy, however, that of the total errors detected, including those that were detected in the comparative testing which effectively constituted a separate (and thorough) integration test, approximately 80% were detected in the initial validation testing and review process conducted at the module level.

Although 80% error detection at the module level is a good record for an initial implementation, it falls short of the reliability level required in operational EW software, and improved test coverage is indicated. It should be stressed that, while the test coverage requires refinement, the test procedures, which require the demonstration of a given level of coverage based on the program design, proved adequate. Without a structured design on which to base test plans, a level of test coverage is difficult to specify, and its effectiveness cannot be evaluated.

5.6 Psychological Factors

A recurring problem in evaluating the effectiveness of programming procedures is the separation of effects due to the procedures as such from effects due to the software development team implementing the procedures. In the present case, all contributors to the effort were aware that the intent of the project was to compare the performance of structured and unstructured programs; since most of the persons involved had a substantial professional commitment to structured design techniques, there was considerable motivation to produce high performance code. Furthermore, this motivation was purely personal. Since the task was performed as an experiment and, at least initially, the structured code was expected to perform less well than the original, there was no formal requirement to produce a given level of performance. Nonetheless, the programming team adopted (of their own volition) a process of independent review of all code produced. This review process was possibly as effective as the formal procedures in increasing reliability and efficiency.

While psychological factors bolstered the procedures, the reverse was also true. The project team viewed the procedures, including the testing, as a means of increasing their own effectiveness. There is an unfortunate tendency to view formal methods (particularly testing) as a club with which to belabor the software development team. In fact, no formal procedures can force high performance; good procedures allow high performance. Testing, both validation and performance testing, can be particularly valuable to programmers in providing immediate and specific feedback. Such feedback considerably speeds up the learning process. It is significant that toward the end of the coding and validation phase of the current effort, most modules

were passing validation testing on the first attempt.

5.7 Potential Benefits of Higher Order Language

It is widely accepted that the use of a higher order language can increase software maintainability and reliability. Although the current study did not address this assumption directly, it is consistent with the project team's experience. For instance, approximately 75% of the errors detected during testing were directly attributable to the vagaries of assembly language programming.

A more significant result in this regard is that large scale revision of software can produce substantial gains in efficiency. Given this finding, it is conceivable that conversion to a higher order language, in conjunction with restructuring, would be technically feasible.

6.0 Recommendations

As noted previously, the current study demonstrates that restructuring is technically feasible, and economically competitive with other means of large-scale revision. The exact benefits deriving from such revision can only be determined in the field. Similarly, the procedures employed require refinement through field experience. Thus the principle recommendation is for a trial fielding of restructured software. This fielding should be accompanied by additional studies and the formulation of a long-range plan for the maintenance process. These recommendations are described in greater detail in the following subsections.

6.1 Development and Fielding Efforts

A restructured section of software, including but not necessarily limited to ETE, should be installed in the ALR-46 OFP. This test case should be used to collect information on the relative ease of maintenance for the restructured software, and the effectiveness and efficiency of the design, coding, and validation procedures. This effort should be accompanied by the development of automated tools to aid the design and documentation process.

6.2 Additional Studies

A study should be conducted to evaluate the technical feasibility of converting to a higher order language such as FORTRAN or PASCAL. Ideally,

this effort should be conducted concurrently with the development of the restructured software for the field test mentioned previously. The bulk of the restructuring effort is in the functional specification phase. Once this is completed, both an assembly language (for installation) and a higher order language program (for testing) could be developed from the same specification with comparative ease. The assembly language and higher order language programs should then be tested to determine the relative efficiency of the two versions. Various levels of hybridization (assembly and higher order language mix) should also be evaluated.

The efficiency study should be accompanied by a reliability study aimed at developing more effective test coverage strategies.

6.3 Long-Range Planning

The results of the efforts above should be used in the formulation of a long-range plan for OFP revision and maintenance. Within the near future, changes in core memory technology (through the installation of electrically alterable read only memory) can be expected to remove the last absolute barrier to the use of higher order language. In the same general time period, the DOD language, Ada will become available. The decision on whether or not to convert to should be based on sound knowledge regarding the potential benefit of a higher order language.

If such conversion is undertaken a global revision of the OFP will be indicated. Such a revision, to be maximally beneficial, should employ procedures which have been thoroughly tested in the field and shown to be effective in producing high maintainability and reliability.

Long-range planning efforts should not be limited to the ALR-46. Structured design, particularly if accompanied by conversion to a higher order language, offers the potential for cutting maintenance costs by taking advantage of cross-system commonalities. Long-range planning should include the definition of a system taxonomy which delineates common functions among the various operational systems. In a global revision, such information can be used to design systems requiring less redundancy in development and maintenance efforts.